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BAILLIÈRE'S

ENCYCLOPÆDIA OF SCIENTIFIC AGRICULTURE

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ENCYCLOPÆDIA OF SCIENTIFIC AGRICULTURE

VOL. II

MADDER—A colouring matter extracted from the root of various species of *Rubia*, chiefly *Rubia tinctorum* and *Rubia peregrina*. Its use in dyeing is very old; the wrappings of some old Egyptian mummies have been shown to have been treated with it. Taken internally by animals, it has the curious property of colouring the bones.

MAGNESIUM (symbol Mg; atomic weight 24·32; atomic number 12). This element occurs naturally in asbestos, dolomite, carnallite, kainite, and other minerals. It is a light silvery metal which burns in air with a bright, highly actinic light, and is used largely in mixtures for flashlight photography. An alloy of it with aluminium is known as "magnalium," and is useful for light castings, such as balance beams, etc.

The sulphate $MgSO_4,7H_2O$ is known as *Epsom salts*, an important saline purgative, and the double phosphate of magnesium and ammonium is present in guanos, urinary calculi, and putrescent urine of animals. Magnesium salts are powerful nervous depressants, and injections of them have been employed as local anæsthetics. It is perhaps as the most important constituent of chlorophyll, however, that it chiefly claims the notice of the agriculturist. It is, according to Willstätter and Stoll ("Untersuchungen über die Assimilation d. Kohlensäure," 1918, and other later papers in the *Ber. d. D. Chem. G.*), the magnesium linkage that plays the principal part in enabling chlorophyll to perform its function in carbon assimilation. It is in very little more than the substitution of magnesium for iron that chlorophyll differs from the hæmoglobin of the blood of animals, and if these metallic groups be ejected from the molecules two substances, phylloporphyrin and hæmatoporphyrin, are formed, which differ only in the possession by the latter of two hydroxyl groups where the former has two hydrogen atoms. The work of Voelcker, published in various numbers of the *J.R.A.S.E.* from 1898 up to 1923, is interesting; it appears that the magnesium-calcium ratio in soils must always be less than unity, but not too much less, if full crops are to be obtained. If in any soil this ratio should be greater than one, it is always a paying proposition to add lime, but care must be taken that the lime added has not been prepared from a magnesian limestone, or, of course, the results may be disappointing. This work has been fully confirmed by pot culture and other experiments at Woburn and elsewhere.

MAIZE—Although on an acreage basis maize is the most important cereal in the world, it is grown in the British Isles as a fodder crop only. For this purpose it was introduced into this country in 1886, but serious initial mistakes in the management of the crop militated against its success, particularly for silage making.

Climate is the limiting factor in the cultivation of maize in these islands, for it does not tolerate frost either in spring or early in autumn, and the crop has thus a very limited growing period. In addition, for rapid growth maize requires a fairly high diurnal and nocturnal temperature accompanied by moderate rains. Such conditions are found only in the south and east of England, and maize growing is consequently restricted to these districts.

If care is exercised in selecting suitable varieties, maize is a splendid silage crop, for it is highly nutritious, heavy yielding, and easy to cut and handle.

Varieties—For many seasons American White Horse Tooth Maize was the variety most commonly grown in England. This variety makes slow early growth, remains green till frost arrives, and is very slow in maturing. As it produces such a large yield of green material per acre, it is very popular, but its actual production of dry matter is inferior to that of some other varieties. It may be grown advantageously for green soiling, particularly when it is not required for feeding till September, but it does not produce good silage.

During the last few years Jaune Gros du Demain, a French variety, has been shown to produce a high yield of dry matter per acre, and as it is early maturing, it is particularly suitable for making into silage. It may be a little too mature for green soiling by the end of September, and for that purpose it is desirable to sow an area of this variety later in the season than usual, or a small area of White Horse Tooth. Saltzer's North Dakota, Longfellow, and Giant Prolific Sweet Ensilage are all early maturing, heavy yielding varieties suitable for silage making.

Soils and Manure—Maize will grow on a wide range of soils, *e.g.*, clay, gravel, fens, but on the clay soils growth is slow, and usually the crop does not become sufficiently mature. The crop is rarely grown on the fens, because stock are not available to utilize it. To obtain quick growth, maize is grown most commonly on light, gravelly soils, but better yields would be obtained on deep, loamy soils. On light soils the crop is most needed to supplement the grass land, which may suffer so much from summer drought.

Such rapid growth as that of the maize needs abundant plant food. It frequently replaces a root crop in the rotation, and is manured as such. On light land it requires fifteen to twenty loads of farmyard manure, 2 cwts. of superphosphate, 2 cwts. of a quick-acting nitrogenous manure, 3 cwts. of kainit, per acre. The farmyard manure should be well rotted and ploughed in during the winter, and the artificial manures applied in April, with the exception of the nitrogenous manures, which should be applied at the time of drilling.

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Sowing—A deep seed-bed, such as that required for potatoes, is necessary to facilitate root development. The seed must be buried by 2 to 3 ins. of soil (the greater depth for light soils), for birds are particularly troublesome to the germinating crop. To reduce the risk of bird damage, the seed may be immersed in tar, and dusted with slaked lime to dry it prior to drilling.

The seed may be drilled with an ordinary corn drill, with drills 18 to 24 ins. apart, or be ploughed in in alternate furrows. When growing the crop for silage, the drills may be 30 ins. apart, and this spacing gives ample light to promote early maturity.

Late spring frosts prevent drilling before the middle of May, but the crop may be successful if drilled up to the middle of June. The seeding rate varies between 1 and 3 bushels per acre, usually 1 to 1½ bushels; a lighter seed rate should be used where the crop is being grown for silage for early maturity, and to eliminate the necessity of singling.

The crop must be harrowed thoroughly to cover the seed, and if weeds grow profusely, a repetition is necessary just before the plants appear above the surface of the soil. The crop is horse-hoed frequently until it is too tall, and hand-hoed once, but it is not usually considered necessary to single the crop, unless it has been planted too thickly for silage, in which case it may be set out, leaving the plants 12 ins. apart in the rows. Maize grows sufficiently rapidly to kill weeds by shading.

Utilization—The crop may be used for green-soiling in August and September, when it should be cut daily, close to the ground, by means of a hook (for the stem is too tough to scythe), and carted on to pasture to dairy, cattle, young, or store stock. As with other soiling crops, excessive wastage occurs when the crop is fed in yards, unless it is cut into 4 to 6 in. lengths, by means of a special cutter. Unquestionably, the largest financial return will be obtained by feeding the crop to dairy cows on pasture.

Maize is a particularly useful crop for silage, provided a suitable variety is chosen for the purpose, for it enables the silo to be filled at the end of the summer, after it has been partially emptied by summer feeding. (See Ensilage.) An immature crop makes poor silage, since the excess of water inhibits the fermentation so necessary to produce good silage; thus, the cobs should be well formed, and the grain just passing from the milk stage, before the crop is cut.

Maize may be fed as any other silage, but as it is poor in proteins either hay, or concentrates rich in protein, should form an addition to the ration.

Yield—The yield of a crop of green maize depends very much on the seasons, the soil, and the variety, but usually the yield lies between 8 to 30 tons when cut; 20 tons have not infrequently been obtained from very light land which has been well manured. At the end of September the crop may produce 2 to 4 tons of dry matter per acre,

MAIZE (*Continued*)—

the equivalent of a crop of 15 to 30 tons of roots per acre. Since the yield is as large as that of many of the roots, maize is an important crop, for, with no singling, it may produce an equal amount of food at a lesser cost. As mentioned above, the limitations to its more extended cultivation are imposed by climatic considerations. (For the feeding value of maize and maize products see Feeding Stuffs, Foods and Feeding, and Poultry.) F. H. G.

MALT COOMBS, OR CULMS—For composition, feeding and manurial value see Feeding Stuffs.

MANGANESE (atomic weight 54·93; atomic number 25). A metallic element used for strengthening and toughening steels. Cast manganese steel (Mn 7 per cent. +) is the toughest material known. The compounds are of little importance in agriculture. Potassium permanganate ($KMnO_4$) is a useful disinfectant and deodorant, while a solution of sodium permanganate has long been sold under the name "Condy's fluid" for similar purposes. The question of toxicity of manganese in soils has been investigated by Dr. Brenchley of Rothamsted, who concludes that it exerts a toxic influence upon the higher plants, if it is presented in high concentration; failing this, there appears to be a definite stimulation which overshadows the small toxic effect (see Brenchley, "Inorganic Plant Poisons and Stimulants," p. 78 *et seq.*). The normal signs of manganese poisoning in plants is a leaf spot and withered, browned roots. A. J. Codling, as the result of unpublished experiments on acid soils, is of the opinion that this toxicity may be due in part, at all events, to soluble manganese, which is precipitated when the soil is neutral or alkaline. The chloride and sulphate have been used for checking grey spot of oats. (See Diseases of Cereals, under Wheat.)

MANGOES—For methods of preservation and refrigeration see Refrigeration.

MANGOLDS—In southern England, where swedes are often uncertain, mangolds are a most useful root crop, particularly during the latter part of the winter and in early spring. It has been found that the crop can be relied upon to give a heavy weight of valuable succulent food per acre, hence for many years the acreage increased progressively until it stood at about 300,000 for England and Wales. Recently, with the rapid development of the sugar-beet industry, the area devoted to mangolds has somewhat declined, and in 1930 it was 288,500 acres. (See Acreage Map, under Turnips and Swedes.)

Botanical Description—The mangold belongs to the genus *Beta* of the Natural Order Chenopodiaceæ, and is thus closely related to the wild sea-beet, and the cultivated garden and field sugar-beet. It is a biennial plant which, during the first season, stores reserve food material in the so-called "root," and flowers and fruits in the second season.

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The "seed" really consists of two or three fruits grown together, each containing a small and somewhat kidney shaped true seed. After germination the long, narrow cotyledons appear above ground and function as leaves.

As growth proceeds, the hypocotyl and the upper portion of the tap root swell and form what is known as the "root"; this swollen part acts as a storage organ for reserve food material. The stem is contracted and bears many leaves; these are smooth, somewhat ovate in shape, and are borne on a definite petiole or leaf stalk. In the second year the short stem elongates into a branched stem, 3 or more feet high. The inflorescences occur at the extremity of the main stem and of the branches. The flowers are very small, with a five-partite perianth—five stamens and a one-celled ovary.

Varieties of Mangolds—There is a large number of varieties of mangolds; these may be classified according to the shape of the roots and colour of the flesh as follows:

(*a*) *Yellow Globes* have a yellow skin and white flesh. They are vigorous in growth and well suited to poor land. As a rule it is comparatively easy to secure a "plant"; on good land they grow an enormous weight of roots, with a low percentage of dry matter; they are easy to lift.

(*b*) *Golden or Yellow-fleshed Globes* are similar in shape to yellow globes, but grow a smaller crop; the roots, however, contain a higher percentage of dry matter. They, also, are easy to lift.

(*c*) *Red and Yellow Intermediates* are fairly long, and not so thick as the globe varieties; they grow satisfactory crops of good feeding value, and are easy to lift.

(*d*) *Golden or Yellow-fleshed Tankards* are best suited for good soils and a favourable climate; the roots keep well until late in spring. They yield a comparatively small crop, which is, however, of high feeding value.

(*e*) *Long Reds* are suited for deep soils, and especially for peats. The roots are long and difficult to lift on heavy soils. On suitable land they produce very heavy crops, and as the percentage of dry matter is high, they will under such conditions yield a greater weight of feeding material per acre than other kinds.

(*f*) *Sugar Mangolds* have white, firm flesh, and the roots are of the long, intermediate type; they somewhat resemble sugar-beet in type.

Feeding Value and Yield per Acre of Various Varieties—Investigations carried out by the late Professors Wood and Berry (*J. Agric. Sci.*, vol. iii., part iii.) showed that the feeding value of Long Red mangolds compared with that of Yellow Globes is, approximately, as 116 : 100. A comparison of Long Red and Golden Tankard indicated that there is no appreciable difference in the feeding value of these types. As the percentages of dry matter are practically identical, the percentage

MANGOLDS (*Continued*)—
of this constituent in mangolds is a very fair guide to their nutritive value.

It follows, therefore, that in making the choice of the most suitable variety to grow, two factors must be considered, the yield per acre and the percentage of dry matter, the object being to choose that variety which will grow the greatest weight of dry matter per acre.

The following figures were obtained in the investigations referred to:

Name of variety.	*Yield per acre.*	*Dry matter.*	*Sugar.*	*Nitrogen.*	*Dry matter per acre.*	*Sugar per acre.*
	Tons.	Per Cent.	Per Cent.	Per Cent.	Tons.	Tons.
White-fleshed Globe	30	10·7	6·3	0·165	3·20	1·88
Yellow-fleshed Globe	25	13·4	8·2	0·181	3·35	2·05
White-fleshed termediate . ..	27½	12·0	7·1	0·168	3·29	1·91
Yellow-fleshed Tankard . ..	24½	13·1	8·0	0·186	3·22	1·96
Long Red . ..	30	13·1	7·9	0·157	3·92	2·36

In these tests, therefore, Long Reds produced 20 per cent. more dry matter and 18 per cent. more sugar per acre than the other varieties. But they do not suit all soils, and on some are troublesome and expensive to lift.

In 1925, and subsequently, trials of mangolds at several centres were conducted by the National Institute of Agricultural Botany, and particulars of these are available before publication by the courtesy of the Director of the Institute. A technique of testing has been evolved with a view to reducing experimental error, and forming an opinion as to the reliability of the results.

In 1926-28 trials were conducted with the types Yellow Globe, Red Intermediate, Golden Tankard, and Orange Globe. Taking all factors into consideration, the conclusion reached was that the Red Intermediate type of mangold has shown itself to be the most satisfactory of those tested, for in all three seasons its high feeding value and reasonably good keeping qualities made it preferable to Yellow Globe. Although Golden Tankard exhibited the best keeping qualities, its small crop, and particularly the low yield of dry matter, accounted for its being placed below both Red Intermediate and Yellow Globe.

In 1928 single plots of 178 named varieties of mangolds were grown at Cambridge and examined for general vigour, trueness to type, and dry matter and sucrose content. Of these, seven varieties of the Globe type and five of the Intermediate type were selected for accurate trial, repeated at six centres in 1929. It is pointed out that, as only one

MANGOLDS (*Continued*)—

season's trials are available, the report must be considered as no more than interim, and deductions can only be tentative. Although the trials did not lend themselves to accurate direct comparison of varieties of the two types, there is little doubt, it is stated, that the outstanding variety in 1929 was Kirsche's Ideal. Its high yield of nutritive matter, combined with its comparatively low total yield (thus affording economy in labour), make it a variety of considerable promise, despite its tendency to bolt. Garton's Orange Globe made the second best showing, Carter's Lord Warden third, and Garton's New Sugar next, but the difficulty of lifting this variety, and its tendency to bolt, detract from its merit.

Judging the results of Wood and Berry and of the National Institute of Agricultural Botany concurrently, it appears that where the land is unsuitable for Long Reds, Intermediate types of mangolds are the best to grow, and that of these the Austrian variety, Kirsche's Ideal, is extremely promising.

Suitable Climatic and Soil Conditions—Mangolds succeed best under climatic conditions such as prevail in that part of England which lies south of York. They grow well in a moderately dry and warm summer, and on heavy land the best crops are not infrequently obtained in a comparatively dry season. On lighter land, a heavier summer rainfall is required.

Although mangolds have a wonderful capacity for growth in a comparatively dry time, it sometimes happens that the crop is reduced by such conditions during certain periods of its growth. Thus, a very dry April and early May not infrequently delays germination and results in a poor "plant," especially on heavy land and after a wet, but mild, winter. The absence of frost results in a poor tilth, the soil sets into clods, and the seed consequently fails to germinate regularly. Nevertheless, judged on the whole, mangolds must be regarded as a crop most suitable for the warmer and drier part of Britain.

This is fully recognized by growers, and statistics show that mangolds are the most popular root crop grown in the south, whereas in more northerly and westerly districts, where cooler and moister conditions prevail, swedes occupy the larger acreage. It is thus significant that while the area devoted to mangolds in Scotland is very small, the acreage of swedes is large.

In southern and eastern Ireland, where the weather is usually mild, and there is an adequate summer rainfall, excellent crops of mangolds are obtained.

Mangolds may be grown on a very wide variety of soils, but succeed best on a deep, easy-working loam; very heavy crops are also obtained on fen soils.

Position in Rotation—As a rule mangolds are grown in the root shift, in the Norfolk four-course rotation—roots, barley, leguminous crop, and wheat. Where, as is often the case, various modifications of

MANGOLDS (*Continued*)—

that rotation are adopted, mangolds generally succeed a cereal, and are in turn followed by a spring-sown cereal, in which clover or clover and grass mixtures are frequently sown. Occasionally, mangolds are followed by wheat.

The arrangement whereby mangolds follow a cereal is quite satisfactory provided the stubbles are fairly clean. The time which elapses in spring before mangolds must be sown is so short that very dirty land cannot be cleaned satisfactorily. In addition, a thorough cleaning in spring may result in serious loss of moisture, and consequently in a poor "plant" of mangolds. Hence, it is not wise to put mangolds in after a very weedy cereal stubble, unless the land can be cleaned satisfactorily in autumn.

Occasionally, mangolds are grown continuously on the same land year after year. This can be done satisfactorily provided they are not attacked by any disease. On the whole, however, it is a better procedure to grow them in rotation, even if the rotation is merely a cereal alternating with the mangolds.

Preparation of the Land—Immediately the previous cereal is removed, the land should, if possible, be broken up in some way, either with the plough or cultivator, and, given favourable weather, several cultivations may be given with suitable implements, such as cultivators, duckfoot, or ordinary harrows, and the weeds collected and burned. In a wet autumn, the land is best ploughed immediately after the corn is removed; this buries weeds, and largely checks their growth.

If the land is clean only one ploughing is necessary on heavy land —the farmyard manure being applied immediately after harvest and the land ploughed deeply.

Mangolds on the Flat—In the drier districts in England mangolds are usually grown on the flat, and the preparation of the land then differs to some extent from the system followed when they are grown on the "baulk," "ridge," or "drill." On heavy land farmyard manure is usually applied in the autumn after the cleaning operations referred to above; it is ploughed in deeply, and no further ploughing is necessary before the mangolds are drilled. As soon as the land is dry enough, and shortly before it is hoped to commence drilling, the land is worked, first with heavy, and then with light harrows, and any couch grass present brought to the surface if possible. It is important to avoid ploughing heavy land in spring, as otherwise the winter tilth, which is so important to secure even germination of the mangold seed, will be buried, and sticky clay, which will dry into hard clods and so form a most undesirable seed bed, brought to the surface.

On light land, even in a dry climate, the land may be ploughed in spring if necessary, but it is important to avoid any preventable loss of soil moisture, for its lack in the surface layer of the soil is the cause of many faulty "plants" of mangolds. Heavy rolling, followed by harrowing, helps to conserve moisture, and should usually be carried out on all types of land before drilling.

When a satisfactory tilth has been obtained and the land is clean,

MANGOLDS (*Continued*)—

the seed is drilled with the ordinary corn cup drill, a special cylinder being used and the coulters being set at the required distance apart. The seed must not be drilled too deeply; probably ½ to ¾ in. of soil is adequate cover.

Mangold rows vary in width according to the views of the grower, the type of land, and the quantity of weeds present. On heavy land, or where the land is not very clean, wide rows are often used, 24 ins. even up to 28 ins. being common; the wide rows greatly facilitate cleaning. On lighter land, and where the land is clean, the rows may be narrower, 16-in. rows even being sometimes adopted.

Where the land is clean probably heavier crops are obtained with fairly narrow rows, say 21 ins., as by this means it is easier to obtain a full number of roots per acre. There is not often very much gained by having the rows narrower than this even on light land, and on heavy land 24 ins. is a very convenient width; narrow rows mean more hoeing.

The system of growing mangolds on the flat is well suited to the drier parts of England, and it is probable that where the rainfall is low heavier crops can be grown by this method. Cleaning, however, is more difficult than where they are grown on the ridge or baulk.

Mangolds on the Ridge, Drill, or Baulk—When grown on this system the land is cleaned as much as possible in autumn; on heavy land in certain districts the baulks are then opened, and left in this condition all winter—the weathering action of frost and rain breaking down the clods and thereby obtaining a good tilth. In early spring the farmyard manure is put out in the baulks and the earth closed upon it; in this way any small weeds which grew during the winter are buried. Sometimes the farmyard manure is put out in autumn and the baulks closed, and when this is done they are harrowed down and re-moulded up in spring to destroy weeds.

On easy-working land and in districts where there is not the same fear of the land losing an undue amount of moisture, the baulks or drills are made in the spring, after working the land to a good depth to destroy and remove weeds, and to make a good tilth. The farmyard manure is then put out and the baulks closed. Very often the seed is drilled at once, whilst the soil is moist and the conditions are favourable for germination.

The system of growing mangolds on the ridge, baulk, or drill possesses advantages in that it is much easier to clean the land. The baulks are usually 24 to 30 ins. apart, and not only a horse-hoe, but a heavy drill grubber can work between them, thus permitting thorough cultivation between the rows. In dry districts the ridges should not be too high, and if well rolled down, the top of the ridge may be only slightly above the general level of the soil; in this way there is less risk of drying out.

Manuring—Mangolds are sensitive to a deficiency of lime in the soil, and where this is pronounced they fail completely. Very often there are large patches which are more deficient in lime than the rest of the

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field. Where this is the case a satisfactory " plant " may be obtained on the major portion of the field, whereas the patches deficient in lime produce nothing but sorrel and spurrey. In these circumstances it is useless to attempt to grow mangolds until lime in some form has been applied. The quantity necessary will vary with the sourness of the soil, but 2 tons of quicklime per acre, or its equivalent in some other form of lime, may be taken as a suitable quantity for land exhibiting a serious lime deficiency. The lime should be applied, if possible, several months, or preferably a year, before the mangolds are drilled. (See Lime and Liming.)

At Rothamsted manurial experiments have been conducted with mangolds for a long period. Russell (" Manuring for High Crop Production," Cambridge University Press) shows that on an average of twenty-seven years farmyard manure alone gave 17·4 tons per acre, and farmyard manure + nitrate of soda, 24·7 tons.

Mangolds have been grown on unmanured land at Rothamsted for a long time, and have produced only about one-fifth of an average crop. Cereals grown in the same way have yielded from one-half to one-third of a crop. This indicates the larger response of mangolds to added manures.

In a Cambridge Experiment (Cambridge Reports, " Guide to Experiments," 1905, p. 36) 10 tons of farmyard manure gave 24 tons 8¾ cwts.; whilst when ⅞ cwt. sulphate of ammonia, 1¼ cwts. nitrate of soda, 6 cwts. super, and 1½ cwts. of sulphate of potash were applied in addition to the farmyard manure, 31 tons 13¾ cwts. of roots were obtained. The oats and " seeds " which followed the mangolds also benefited substantially from the residue of the artificials.

Manurial experiments with mangolds were conducted in North Wales at a large number of centres over a period of twenty-two years (University College of North Wales, " Summary of Experiments on the Manuring of Mangels," 1892-1915). In these trials farmyard manure proved essential to the production of a large crop of mangolds. Ten to 15 tons of farmyard manure per acre gave an average increase of 9 tons 5 cwts. On land receiving 10 tons of farmyard manure per acre, an extra 10 tons proved unprofitable when used in conjunction with a dressing of complete artificials, while in the absence of artificials they produced an average increase of 3 tons 6 cwts.

At thirty-five centres a dressing of 128 lbs. of nitrate of soda, 349 lbs. superphosphate, and 82 lbs. muriate of potash used in conjunction with farmyard manure proved, on the average, as effective as a dressing of double this quantity.

Taking the average of all the experiments, potash manures gave only a moderate return, but in some cases a very decided and profitable response was secured. Kainit was superior, unit for unit, to sulphate of potash and to flue dust.

Nitrogenous manures gave a small return. The majority of the trials were carried out on soil already containing large reserves of nitrogen collected by the wild white clover of the previous ley. Nitrate of soda proved to be superior to sulphate of ammonia in trials

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carried out at thirty-five centres, the average superiority being 25 cwts. per acre (8 per cent.). In a series of trials conducted from 1921-25 there was no appreciable difference between the effect of muriate and of sulphate of ammonia, but nitrate of soda proved slightly superior to both.

Common salt gave a considerable and profitable increase in crop when no potash manure was used, but when added to a 4-cwt. dressing of kainit the effect of the salt was small.

In Ireland manurial experiments with mangolds at a large number of centres showed that excellent results were obtained from a good dressing of farmyard manure in conjunction with 2 cwts. sulphate of ammonia, 4 cwts. superphosphate, and 4 cwts. salt.

In Somerset (J. H. Burton, "Report on Field Experiments," 1914) a dressing of sulphate of ammonia, nitrate of soda, and superphosphate, in addition to farmyard manure, gave a profit of 3s. 10d. as compared with farmyard manure only.

At Saxmundham Experimental Station in Suffolk, on heavy chalky boulder clay, satisfactory crops are obtained only where either farmyard manure or phosphates, or both, are used.

Over a period of four years, 1923-26, no manure gave 3 tons 6 cwts.; 6 tons farmyard manure annually (*i.e.*, 24 tons in the rotation) gave 22 tons 10 cwts.; a complete dressing of artificials, 2 cwts. nitrate of soda, 2 cwts. super, and 1 cwt. muriate of potash, annually, gave 23 tons 7 cwts. The omission of the super from this dressing reduced the average crop to 5 tons 3 cwts.

In another series of experiments at Saxmundham, over four years, no manure gave 4 tons 14 cwts. Another plot, which received 10 tons of farmyard manure per acre to the wheat preceding the mangolds, and no manure actually applied to the mangolds, gave 13 tons 6 cwts., showing the remarkable residual effect of the farmyard manure (A. W. Oldershaw, "Report on Field Experiments, East Suffolk," 1923-26). Wood and Berry (*J. Agric. Sci.*, vol. i., part ii.) showed that excessive applications of nitrogen delay ripening and decrease the percentage of dry matter in mangolds; farmyard manure also decreases the percentage of dry matter. Apparently very small mangolds, smaller than any farmer would care to grow, are very rich in dry matter, and very large mangolds, correspondingly watery. A small variation in average-size mangolds does not make much difference. It is not a practical proposition, however, to grow very small roots, as this would result in very small yields of dry matter per acre. Under-manuring, although it might result in the production of roots of high feeding value, would not produce a large return of dry matter per acre. Thus, it is probably most remunerative to manure fairly generously, but not excessively, with both farmyard manure and artificials. If the conditions are such that the roots are apt to grow to an excessive size, they can be left closer together, and a larger number of roots grown per acre. This will in most cases maintain an average size of root, when a small variation in size makes little difference in the percentage of dry matter. In this way the maximum weight of dry matter—which is

MANGOLDS (*Continued*)—

what mangolds are grown for—will be obtained. There is evidence that very profitable results from the application of artificial manures are not very likely to be obtained unless there is a fairly large number of plants per acre—probably from 22,000 to 25,000 are desirable.

General Effect of Manures—*Farmyard manure* undoubtedly gives extremely good returns when applied to mangolds; usually up to 20 tons per acre is a profitable application.

Nitrogenous manures also have a striking influence upon the weight of crop, but, as previously noted, the percentage of dry matter in the roots does not increase proportionately with the amounts of manure applied.

Many experiments have been conducted to test the relative efficiency of the various sources of nitrogen, and, in the drier parts of England, probably nitrates are most effective. On the other hand, ammoniacal nitrogen is usually cheaper per unit, and it is usually quite satisfactory, especially with an ample rainfall.

A useful plan is to apply part of the nitrogen as sulphate of ammonia, mixed with the other manures before drilling the seed; then, after singling, a dressing of nitrate of soda or nitrate of lime may be given. If an unsatisfactory "plant" has been obtained, it is improbable that a heavy dressing of nitrate will be profitable. Calcium cyanamide may very well be used as a source of nitrogen, especially on land poor in lime, but it should be worked into the soil at least a fortnight before drilling the seed, or the germination of the seed may be affected adversely.

Phosphatic manures are desirable on almost all types of soil, but are most important on the heavier types; light land does not as a rule require so much phosphate. Phosphates are especially useful in helping rapid development of rootlets in young seedlings. In this way they may help the young plants to survive, and thus assist in obtaining a better "plant." At Saxmundham Experimental Station, on heavy land, certain plots have received neither farmyard manure nor phosphates for thirty years, and on these practically no crop is obtained, even where ample nitrogen and potash is added.

Potash and Common salt—On certain soils potash has a very beneficial effect. Common salt in combination with nitrogen and phosphates has been tried at many centres in Ireland, and was found to give a remunerative increase. This was also the case in Herefordshire, where an increase of 3 tons per acre was obtained by the use of 3 cwts. of salt per acre. Salt is undoubtedly extremely useful for mangolds on light loams and light soils generally. Near fish-curing centres "fish" salt, containing fish heads, is not infrequently obtainable, and the fish residues present in this case, being rich in nitrogen and phosphate, are also extremely beneficial to the mangolds. On heavy land salt has a very bad effect upon the texture of the soil, and must be used sparingly, if at all.

Where salt is not cheap, kainit, which contains a substantial pro-

MANGOLDS (*Continued*)—

portion of salt, may very well be used instead. The potash present in the kainit, when not all utilized by the mangolds, will benefit succeeding crops, such as the clover, usually sown in the cereal following the roots; hence on a soil especially needing potash it may be better to use kainit than salt.

General Suggestions on the Manuring of Mangolds—On land containing a sufficient supply of lime:

Dressings per acre:

Farmyard manure up to 20 tons.
Sulphate of ammonia, ½ to 1 cwt., applied before drilling the seed.
Superphosphate from 2 cwts. on light land to 4 cwts. on heavy land.
Kainit, 4 to 5 cwts. on light land, the quantity being reduced to 2 cwts., or less, on heavy land. Where kainit pans the land down and has a deleterious effect on the tilth of land, it may be omitted and a small dressing, say ½ cwt., of muriate of potash may be used where the land responds to potash.

If agricultural or fish salt can be obtained cheaply, it may be substituted for kainit, to the extent of 4 to 5 cwts. on light land. In this case, especially on light land, it will be desirable to use in addition, say, 1 cwt. of muriate of potash.

After singling 1 to 2 cwts. of nitrate of soda or nitrate of lime may be applied in one or two dressings.

Where the land is somewhat, but not very seriously deficient in lime, the dressings of artificial manure may be modified in such a way as to use substances which do not impoverish the soil in lime, thus:

1. Nitrate of soda or nitrate of lime, calcium cyanamide, or nitro-chalk, should be used instead of sulphate of ammonia. These substances are best not mixed with the other manures. If nitrates or nitro-chalk are used in place of sulphate of ammonia, ½ to 1 cwt. per acre may be applied at the time of sowing, or a week after. Subsequent dressings of nitrate may be given, as in the case of land containing ample lime. If cyanamide is used, 1 to 2 cwts. per acre may be worked into the soil not less than a fortnight before drilling the seed (a less interval than this may involve injury to the germinating seedlings).

2. In lieu of superphosphate it is best to use an alkaline or neutral phosphate—2 cwts. of basic superphosphate on light land up to 4 cwts. on heavy land may be used; 2 to 4 cwts. of steamed bone flour would also be a useful phosphatic dressing for sour land, the smaller dressing being for light land. North African phosphate (even when ground to 120 mesh) and basic slag are rather slow in their action for mangolds. Still, on acid soil, especially in districts where there is usually an ample rainfall in spring, they may be used as a source of phosphate. Four to 5 cwts. of 60 per cent. North African phosphate, or 6 cwts. of 30 per cent. basic slag, or its equivalent in other qualities, would be suitable dressings. Basic slag is especially suited for heavy land. It would be well to apply both manures some weeks or even months before drilling the mangolds.

MANGOLDS (*Continued*)—

Sowing—Mangolds may be drilled any time between April 1 and the end of May with a reasonable prospect of a crop; sometimes they are drilled even earlier than April 1. Where the land is clean, there is little doubt that in an average season early sowing is best, especially on loamy soil. On the other hand, on very heavy clays, too early sowing, followed by a period of cold, wet weather, may result in the roots being stunted in growth; on such soil the first week in May is probably the best time.

Regularity of Plant, and Number of Roots per Acre—There is good reason to believe that, as in the case of sugar-beet, very heavy crops of mangolds can only be secured with a regular " plant " and a fairly large number of roots per acre. A small number of large roots per acre will not, as a rule, give a really heavy crop. For a number of years the Stowmarket (Suffolk) Farmers' Club have made a practice, in their annual root competitions, of counting the number of roots per rod, and much valuable information has been obtained thereby. The number of roots varies in a most striking way. Thus, in 1929, in the published list the largest number of roots per square rod was 191, and the competitor who secured the first prize with this number obtained a crop of 41 tons 6 cwts. per acre. The lowest number was 80 roots per rod; two competitors had this number with crops of 24 and 19 tons per acre respectively. The writer investigated the subject to some extent, and came to the conclusion that to obtain really heavy crops—40 tons and upwards per acre—160 or more roots are required per rod, or an equivalent of approximately 25,000 roots per acre.

To obtain this number, either the rows must be fairly close together or the roots fairly close together in the rows. As previously noted, the most convenient and suitable distance apart of the rows depends upon the character of the land and the quantity of rubbish present. If the rows are 2 ft. apart, and the roots 9 ins. apart in the rows, and absolutely regular, about 29,000 plants per acre would result. But the plants are practically always slightly irregular in the rows; hence, if 9 ins. apart is aimed at, the probability is that the average distance apart will actually work out at about 10½ ins., which with 2 ft. rows gives roughly 25,000 plants per acre. When commencing to chop out, it is thus worth while to do a trial square rod first, for there is no doubt that care is necessary in chopping out and singling, otherwise the crop may be seriously reduced.

If the rows are closer than 24 ins., the roots may be chopped out further apart in the rows, say, at 10 ins., then the average will probably be 12 ins. With 21-in. rows an actual average of 12 ins. from root to root would give approximately 25,000 roots per acre, which, as previously stated, seems a very suitable number. If the rows are wide apart, say 28 ins., special care should be taken that they are not thinned too much in the rows. If they are left too thin, large roots will be obtained, but there will not be enough of them to produce a heavy crop, while in addition they will probably be low in dry matter. (See Sugar-Beet; and Seed, Spacing of.)

MANGOLDS (*Continued*)—

Storing—If lifted carefully, most varieties of mangolds will keep fairly well, but Long Reds and Golden Tankards are better in this respect than Yellow Globes and Intermediates. Mangolds are more readily injured by frost than swedes. The most effective protection for mangold clamps seems to be loose straw or grassy material covered with earth.

Weight of Crop per Acre—The average yield of mangolds per acre in this country is about 19 tons, but this is greatly exceeded in many cases. On good land, and with careful cultivation, 40 tons per acre is not uncommon. Mangolds are a suitable crop for high farming, and there is little danger of the crop being spoilt by too fertile a condition of soil, as in the case of cereals. The standing charges, rent, many tillage operations, and much of the hoeing are the same for a good or a bad crop; hence, the cost per ton of a large crop is much less than that of a small one. By careful attention to autumn cultivation, by suitable manuring, by the conservation of moisture in spring, by the adoption of every possible means of securing a regular "plant," and by taking care that the mangolds are not checked by weeds, the average yield could be greatly increased. There is also a possibility that the percentage of dry matter, and hence the feeding value of the roots, may be increased by the efforts of the plant breeder, as has been done in the case of the sugar-beet.

Utilization of the Crop—The feeding value of mangolds has been shown to depend upon their dry matter, of which a large proportion is sugar. Succulence in a winter food, however, is almost certainly of value, as is also palatability—a quality which mangolds possess in a high degree. As they are deficient in protein care must be taken, especially in the case of young stock and milch cows, that the animals receive a sufficient supply from other sources.

There is considerable variation of opinion as to the most suitable quantity of mangolds to feed, and to a certain extent it will vary with the weight of roots available. Cattle will eat 1 cwt. or more daily, but it is unlikely that this is an economical quantity, and 40-60 lbs. daily for fattening cattle and milch cows is probably more suitable, although when there is an abundant supply this quantity may be exceeded.

Mangolds are often fed to sheep, being thrown on to grass or carted to a fold; perhaps they are most popular for feeding to ewes after lambing. Horses and pigs also relish a small quantity daily, and probably benefit in health by this addition to their ration.

Mangolds are not very suitable for feeding until the middle of December, but they continue to be a very valuable feed during spring and early summer. There is some difference of opinion as to the advantage or otherwise of pulping mangolds, but where the roots are small there is danger of cattle choking if they are fed whole.

The pulped roots are often mixed with chaff, and serve to render such food more palatable. When pulping has to be done by hand,

MANGOLDS (*Continued*)—
however, it entails much labour, and the resultant advantage does not appear to be very great.

Seed Production—Great care is taken by seedsmen in selecting mangolds intended for seed growing, qualities such as high dry matter content, trueness to type, keeping quality, etc., being taken into consideration. In growing seed under ordinary farming conditions, the following methods are often adopted:

The seed is drilled in July, after a summer fallow, in rows 12 ins. apart, at the rate of 20 lbs. per acre, or it may be broadcast. The plants are allowed to remain *in situ* until early spring, when they are transplanted. This method is only successful if the winter is mild, for mangolds are very susceptible to injury by frost.

An alternative method is to store the small plants in autumn, and transplant out in early spring, in rows 28 ins. apart and 12 ins. apart in the rows. The plants may be put out on the flat or on the ridge, and as the inflorescence develops, the leading shoot is nipped off to induce branching. When ripe—usually in September—the crop is cut by means of hooks, the sheaves hang together and need not be tied. Stooks are erected in a few days' time. When thoroughly dry the crop is carted and thatched at once. Thrashing is done with the ordinary travelling thrashing mill in the usual way.

A. W. O.

MANIOC MEAL—For composition and feeding value see Feeding Stuffs.

MANOMETER—An instrument for measuring small differences of pressure; when large pressures are in question, the instrument used is usually called a pressure gauge. A simple manometer may consist of a U tube partly filled with water, or some other liquid such as alcohol or Fleuss oil (which has no appreciable vapour pressure, and is therefore useful where high vacua are in question). One side of the U tube may be connected with the enclosure where the pressure is to be measured and the other left open, or if connected to a second enclosure the difference between the heights of the liquid columns will be the pressure difference between the enclosures in terms of centimetres head of the liquid used. For very low pressures, gauges on other principles like the Chattock gauge are often used, but the McLeod gauge for high vacua is really nothing but a U-tube manometer into one arm of which a large volume of much rarefied gas has been compressed, its volume having been reduced to a known fraction of what it was before.

MANURING, THE PRINCIPLES OF—Manures and fertilizers are substances added to the soil to increase its productiveness. The effect may be to improve the soil as a medium for plant growth, or to supply the plant with essential foods. The word "manure" is generally used for substances that improve the soil as well as the plant food supply—for example, farmyard manure, green manures, lime—while the word "fertilizer" is restricted to those substances that add only plant food without necessarily improving the soil; indeed, some of them may, in certain special circumstances, injure the soil.

MANURING, THE PRINCIPLES OF (*Continued*)—

Plants require a considerable number of substances as food, some in larger amount than others. Those needed in larger amount are carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur, while those needed in smaller amounts are iron, manganese, and for some plants boron.

Of the first group the carbon and oxygen come from the air. The carbon is taken from carbon dioxide, a gas which occurs to the extent of 0·03 per cent. in the atmosphere. It was formerly supposed to come from the soil or the manure, but this view was generally given up as the result of one of the early controversies in agricultural science. Attempts have been made to increase the supply of carbon dioxide in the air by discharging furnace gases into it, or by burning oil in a special stove, and the plants have responded to this gas manuring, but the process has not yet found commercial application, and is indeed practicable only in glasshouses. It may, however, have some future when it is better understood.

The source of nitrogen, like that of carbon, was long in dispute; it was at first thought to come from the soil or manure, then from the air; now, however, it is known to come from the soil. There has been some shifting of opinion as to the particular form in which it is absorbed: the older chemists thought it was taken up as ammonia, which was, they considered, the real nitrogenous food; later it was shown to be usually taken up as nitrate; now, however, a compromise is coming into favour, and there is a growing opinion that the real nitrogenous food is ammonia, but that nitrate is in practice more easily taken up.

The remaining food elements are called the mineral elements; of these calcium, magnesium, and sulphur are usually (though not always) present in the soil in sufficient amount for all plant requirements, as also are iron, manganese, and boron, but phosphorus and potassium are not always, and further additions to the soil bring about increases in plant growth.

Fertilizers in general, therefore, supply nitrogen, phosphorus, and potassium to the plant, but there are occasions when additions of calcium, magnesium, sulphur, iron, and manganese to the soil have been necessary for full and healthy growth.

Unfortunately for the agriculturist, the only safe guide to the fertilizing of a crop is actual experiment; there is no way of discovering beforehand what fertilizers will be necessary to secure maximum growth. Liebig, in 1840, starting from the assumption then current that a substance present in the plant must be there for some purpose, put forward the ingenious idea that the composition of the plant formed a satisfactory guide to manuring; therefore, if you know what the plant takes from the soil, you know what fertilizers to give it. This idea was disproved by Lawes at Rothamsted, and is now given up; it is recognized that the plant will take up from the soil some of everything that can dissolve in the soil water regardless of whether the substance is good or bad; it may indeed absorb a poison as easily as a food. Again, too, it was supposed that chemical

MANURING, THE PRINCIPLES OF (*Continued*)—

analysis of the soil would show what fertilizers were needed, but this, too, proved to be wrong; chemical analysis is useful for comparing one soil with another, and may enable the analyst to make useful suggestions as to manuring, but it can do little more. Direct trial of the effect of fertilizers on plant growth is the only way of obtaining trustworthy information.

The effect of fertilizers on plant growth depends on three factors:

1. The stage of growth of the plant.
2. The quantity of the fertilizer given.
3. The other conditions of growth: temperature, water supply, reaction of the soil.

Stage of Growth—Practically all plants take up their foods in the early days of their growth; any shortage during that period may affect the plant for the rest of its life. In some experiments at Rothamsted barley took up all the phosphate it needed in the first six weeks. But when it was deprived of phosphate during this period it made very poor growth, it was thin and lanky, it formed no tillers and wretchedly poor ears; later additions of phosphate did not put matters right.

This fact, that the plant needs its fertilizers early in its growth, explains the advantage of using soluble or easily available substances in finely powdered condition, and of applying them sufficiently early, and sufficiently near the roots of the plant. Winter-sown corn is a partial exception; growth is practically suspended during winter, but nitrogenous fertilizer is liable to loss, and is best applied in spring when growth is beginning. (See Wheat.)

The Quantity of Fertilizer Given—Horticulturists growing for pleasure and not for profit may make the mistake of supposing that if a small dressing of fertilizer is good, a big dressing must be better. Farmers who have to think of every penny would not make this mistake, but may, on the other hand, stop short of the most profitable dressing. "There is that withholdeth more than is meet, but it tendeth to poverty," said the wise man of old in the Book of Proverbs. The rule is that plants take up part of the fertilizer that is given, and the more given, the more will they absorb up to a certain point, beyond which, however, they can absorb no more. This limit is easily reached for phosphate, but for nitrogen and potassium the plant has a bigger capacity.

The extra fertilizers absorbed may cause the plant to make bigger growth, in which case the yield is increased. But it may simply lie up in the plant without increasing growth; there is then no increase in yield, but a change in composition and in quality, not necessarily a beneficial change. This is illustrated in Table I., which gives the results of a Woburn pot experiment on barley showing the quantities of nitrogen supplied, and the yields obtained.

As the nitrogen supply increased, the uptake of nitrogen by the plant increased, as also did the yield, but not correspondingly; the excess of nitrogen tends to pile up more in the straw than in the grain;

MANURING, THE PRINCIPLES OF (*Continued*)—

indeed, the grain is but little altered until a considerable quantity of nitrogen has accumulated in the plant.

TABLE I.

Yield of Barley and Uptake of Nitrogen in Woburn Pot Experiments for Different Quantities of Nitrogen Supplied.

Nitrogen given as sulphate of ammonia..	None	0·051	0·106	0·161	0·212	0·424	0·857
Yield of grain ..	40·21	40·50	37·69	42·90	38·86	50·81	47·46
Total produce ..	81·82	80·61	78·03	89·61	82·20	97·60	105·30
Nitrogen per cent. in grain	1·47	1·46	1·41	1·37	1·47	1·46	1·64
Nitrogen per cent. in straw	0·36	0·36	0·43	0·40	0·52	0·50	0·63
Total nitrogen in plant	0·649	0·637	0·631	0·727	0·712	0·871	1·075

These results are quite general. They are shown by potassium almost as markedly as by nitrogen; they are, however, less shown by phosphorus. For all three substances the general rule is that the food substances absorbed from the fertilizer bring about increased growth as far as the conditions permit; any excess not used up by the extra growth is stored in the leaf or the straw, but the grain is not affected unless there is a considerable accumulation. Now a leaf is not like a bag into which things can be put and brought out again unchanged. It is altered by the substances that are stored there, so that the leaf containing a high percentage of nitrogen is quite different from a leaf containing less. This is true of the whole plant; its appearance and habit of growth become changed, and indeed it is possible to tell from the look of the plant what things it lacks and what it possesses in too great abundance. Much work is being done on this subject at Rothamsted on agricultural crops, and at Long Ashton on fruit crops. (See Fruit Plants, Manuring of, under Fruit.)

The effect of a fertilizer depends on the conditions; *it causes extra growth so far as the conditions permit;* this ought to be fixed firmly in every farmer's memory. For if the land be waterlogged, or sour, or badly prepared, or if other necessary foods be lacking, the fertilizer has little chance to act. It is no use increasing one food alone unless the plant is sufficiently supplied with others. This is well shown in Table II., giving the results of experiments with potatoes at Rothamsted; some received sulphate of ammonia alone, others received sulphate of potash alone, others again received both. Reading down the table you see the effect of sulphate of ammonia with no potash, sulphate of ammonia with 1 cwt. per acre sulphate of potash, and sulphate of ammonia with 2 cwts. sulphate of potash. Reading across the table you get the effect of sulpahte of potash with no sulphate of ammonia, with 1½ cwts. per acre sulphate of ammonia, and with 3 cwt. per acre sulphate of ammonia. Observe that the sulphate of potash without sulphate of ammonia has little effect;

MANURING, THE PRINCIPLES OF (*Continued*)—
sulphate of ammonia without sulphate of potash has some effect, but not as much as when sulphate of potash is also given; the two fertilizers act best only when they are acting together. The other experiments show that this pair of partners must be combined with adequate supplies of superphosphate to give their fullest action.

TABLE II.

POTATOES: ROTHAMSTED (HARPENDEN FIELD), 1928.

		Without Superphosphate.			*With Superphosphate.*		
		Sulphate of Ammonia (Cwts. per Acre).			*Sulphate of Ammonia (Cwts. per Acre).*		
		0	1½	3	0	1½	3
Sulphate of potash (cwts. per acre)	0			8·00	6·60	8·74	8·26
	1	7·62	9·15	9·76	7·67	9·03	11·05
	2	6·58	8·13	9·74	7·06	8·79	10·63

Standard error 0·33 tons or 3·88 per cent.

POTATOES: ROTHAMSTED (LONG HOOS FIELD), 1929.

		Without Superphosphate.			*With Superphosphate.*		
		Sulphate of Ammonia (Cwts. per Acre).			*Sulphate of Ammonia (Cwts. per Acre).*		
		0	1½	3	0	1½	3
Sulphate of potash (cwts. per acre)	0	4·52	5·10	5·38	4·79	5·52	5·94
	1	4·86	5·26	5·41	5·01	5·90	6·28
	2	4·62	5·30	5·59	4·89	5·77	6·51

Standard error 0·11 tons or 1·96 per cent.

Effect of Season—Experiments of this kind are made at Rothamsted year after year, and careful records are taken of weather conditions. Fertilizers do not always act equally well; in some seasons they act better than in others; the 1928 and 1929 results are examples. Apart from years of bad drought, nitrogen fertilizers are most constant in their action; phosphates and potash are more variable. Of all the weather factors rainfall seems to be the most important at Rothamsted—presumably, also, in most of England, temperature comes next, and actual bright sunshine last in determining yields of cereals. Of the food elements the uptake of nitrogen by the plant is least affected by variations in supply of soil moisture, and the uptake of potassium most affected, being greatest when the water supply is greatest.

MANURING, THE PRINCIPLES OF (*Continued*)—

Weather conditions act differently on different combinations of fertilizers; Fig. 13 shows the effect of 1 in. of rain above the normal in each month on the yield of wheat under three different fertilizer treatments: (1) Plot 5, minerals only, no nitrogen; (2) Plot 10, nitrogen only, no minerals; (3) Plot 13, minerals and nitrogen, *i.e.*, complete manuring. These relationships between fertilizer effectiveness and weather are being closely studied at Rothamsted with the purpose of finding out how to modify the fertilizer recipes for different climatic regions. It often happens that fertilizers act better in seasons of poor growth than in seasons of good growth (bad droughts excepted); they thus tend to level up crop production and reduce the variation in yield from season to season; a sound fertilizer recipe is the most practicable method of changing a bad season into a good one. Fig. 14 shows that the annual variation in yield of wheat on Broadbalk is much less on the fully manured plots than on the others.

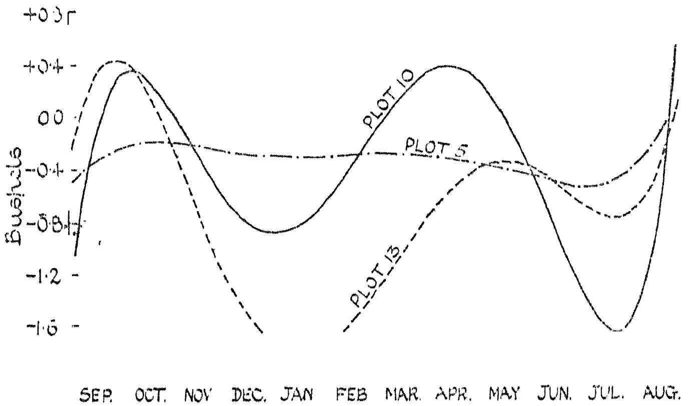

FIG. 13.

Plot 5, Superphosphate + Sulphate of Potash; Plot 10, Sulphate of Ammonia; Plot 13, Sulphate of Ammonia + Superphosphate + Sulphate of Potash.

The Nitrogenous Fertilizers—Detailed descriptions are given elsewhere (p. 345 *et seq.*) of the ordinary nitrogenous fertilizers, sulphate of ammonia, nitrate of lime, nitrate of soda, and cyanamide; we confine ourselves here to their general mode of action. The simplest and quickest in action are the nitrates; the nitrate part is taken up easily by the plant; this is apparently changed first into nitrite, then into ammonia, then into asparagin, and finally into complete proteins. The ammonium fertilizers go through a change in the soil before they are taken up by the plant: the ammonia is changed to nitrite, then to nitrate; this is absorbed by the plant, then changes back first to nitrite, then ammonia, then it is built up to asparagin and protein as before. It seems a very cumbersome procedure, and the explanation is not clear. One reason may be that some of the soil organisms rapidly

MANURING, THE PRINCIPLES OF (*Continued*)—

attack the ammonia and oxidize it to nitrate, getting much of their energy supply in that way, so that the plant has little chance of absorbing ammonia in any case. Another is that the ammonium salts, in decomposing in the soil, leave behind an acid which, unless it is neutralized, would injure plant growth, while nitrates leave behind a base; calcium is beneficial, as also is sodium for certain crops, though it may injure the texture of sticky clay soils. The broad result of the soil changes is that ammonium salts are somewhat slower in action than nitrates, and are on many soils somewhat less effective, especially in rather acid conditions. As they are usually cheaper, the balance still generally remains in their favour. Nitrates and ammonium salts are both soluble, but they differ greatly in the ease with which they can be washed out from the soil by rain; nitrates go readily, ammonium salts do not. Nitrates, therefore, are not applied in late autumn or winter in English practice.

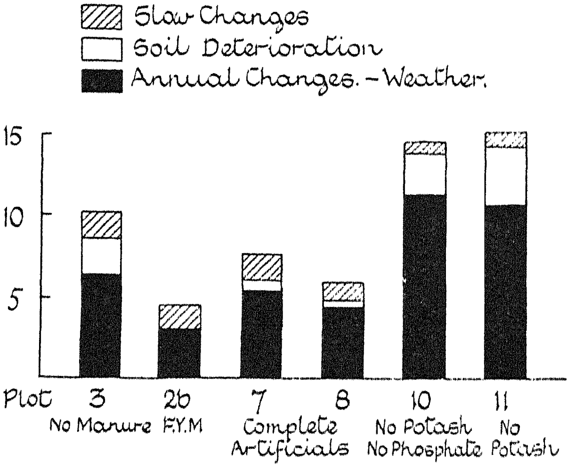

FIG. 14.—SHOWING THE ANNUAL VARIATION IN WHEAT YIELDS ON BROADBALK.

It is sometimes stated that ammonium salts are better in wet seasons than nitrate of soda, but this is not true for British conditions; at Rothamsted, indeed, it is rather the other way about: nitrate of soda is somewhat better than sulphate of ammonia. In tropical countries, however, where several inches of rain may come in twenty-four hours, sulphate of ammonia is distinctly the better.

Cyanamide is in a rather different category; it is as a rule slower in action than ammonium salts, and somewhat less effective, but it is also cheaper, and may therefore work out more economically. It is not absorbed directly by the plant, but is decomposed in the soil first to urea, then to ammonia, then nitrite, and finally nitrate; in certain circumstances some dicyanodiamide is found which is poisonous to

MANURING, THE PRINCIPLES OF (*Continued*)—

plants. Apart from this, the chain of processes is not unlike that for other nitrogen compounds, but there is one important difference: the cyanamide stops the action of the nitrifying organisms for a time, and hence the ammonia remains in the soil as such, and is not at once converted into nitrate. The full implications of this result have not been worked out, but it seems possible that the delay in nitrification would protect the nitrogen against loss from winter rain, and therefore that cyanamide might make a useful autumn dressing for grassland and winter corn. This is being tested at Rothamsted.

The effect of the nitrogen on the plant is to increase the area of the leaf. Nitrogenous fertilizers are therefore of great value for all leaf crops—grass, cereals, mangolds, potatoes, cabbages, and others. The increased leaf area allows of additional absorption of carbon dioxide from the air, so that more carbohydrate is formed in the plant, and out of this more plant substances. One part of nitrogen absorbed by the root allows of the production of some eighty parts of dry matter of non-leguminous crops or forty or fifty parts of dry matter of leguminous crops. As the nitrogen supply is increased, so the leaf area is increased; indeed, small increases of nitrogen may give more dry matter than is strictly proportional to their amounts, so that the percentage of nitrogen in the plant, and particularly in the grain, falls off (this is shown in Table I.). But large increases in nitrogen supply cause the nitrogen to pile up in the plant, mostly in the leaf, but also in the grain, thereby causing changes in habit of growth and in composition. The leaves become very large, dark green, sappy, crinkled as if trying to avoid the sunlight; liable to the attack of certain fungoid pests; vegetative growth continues long, and ripening is delayed. The appearance suggests that the excess of nitrogen is not good for the plant; indeed, some plant physiologists speak of "ammonia poisoning," and they point out that the animal also cannot tolerate excess of nitrogen, but it has special provision for excreting the excess through the kidneys in the form of urea; the plant has no such power. The plant remains normal and healthy, forms its fruit, and ripens in the usual manner only when the carbonaceous part is sufficiently in excess of the nitrogenous part, or, in chemical language, when the ratio $\frac{\text{carbon}}{\text{nitrogen}}$ is round about a certain range of values.

The grain, as already stated, suffers less, but nevertheless it is altered by the excess of nitrogen. Barley has been most fully studied; the excess of nitrogen accumulates mostly in the form of hordein, the amount of which increases regularly with increasing percentage of barley in the grain. The proportion of glutelin remains constant, but that of salt-soluble nitrogen compounds decreases. As the nitrogen increases, so the starch decreases, and with it the amount of extract obtainable after malting; the amount of diastase, however, increases. These changes are disadvantageous to the brewer of beer who wants a large amount of extract and not too much nitrogen; they are, however, advantageous to some of the distillers who want the diastase to break down certain unmalted material added to the mash. As the brewers'

MANURING, THE PRINCIPLES OF (*Continued*)—

demand fixes the price for malting barley, high nitrogen content is a disadvantage; for Spratt-Archer or Plumage-Archer a good value is about 1·35 to 1·45 per cent. total nitrogen. (See Barley.) For wheat, on the other hand, high nitrogen content is usually an advantage; in the winter season 1929 to 1930 the hard Canadian wheats of high milling quality had a nitrogen content of about 2·6 per cent., while the soft English wheats of low milling quality had a percentage of only 1·8.

Recovery of Nitrogen from Fertilizers—The crop rarely takes up the whole of the nitrogen added in fertilizers; in many experiments the recovery has been about 50 per cent.

Potassic Fertilizers—The effect of potassic is closely linked up with that of nitrogenous fertilizers; one is the counterpart of the other. Nitrogenous fertilizers, while increasing the area of the leaf, do not alter its efficiency as a maker of plant substance, *i.e.*, a square inch of a leaf receiving nitrogen makes no more carbohydrate than a square inch receiving none. Potassic fertilizers, on the other hand, increase the efficiency but not the area of the leaf; leaves receiving potassium are no bigger, but they are better than leaves receiving none.

In consequence, potassic fertilizer corrects possible ill effects from excess of nitrogen; for when the plant can no longer increase its leaf area sufficiently to balance the extra uptake of nitrogen with additional carbohydrate, then potassic fertilizer increases the efficiency of the leaves, so enabling them to make more carbohydrate and so balance the nitrogen. This effect is well seen on the Barnfield mangold plots at Rothamsted. The plants receiving additional nitrogen produce considerable leaf, but they are unhealthy, showing markedly all the symptoms already described for excessive nitrogen. But when potassic fertilizer is given, the leaves, although no bigger, make much more sugar and much bigger and better roots; the whole plant now becomes healthy and vigorous. The results are given in Table III.

TABLE III.

EFFECT OF POTASSIC FERTILIZER ON YIELD OF MANGOLDS. ROTHAMSTED AVERAGE FIFTY YEARS, 1876–1928.

		Leaves (*Tons per Acre*).	*Roots* (*Tons per Acre*).
Nitrogen from sulphate of ammonia (412 lbs. per acre)	Potash given	2·81	13·50
	No potash ..	3·61	6·70
Benefit from potassic fertilizer ..		Nil	6·8 tons.
Nitrogen from rape cake (1,000 lbs. per acre)	Potash given	2·87	18·14
	No potash ..	2·84	10·16
Benefit from potassic fertilizer ..		Nil	8 tons.

Potassic fertilizers especially benefit leguminous plants, clover and others, enabling them better to grow and to survive bad winters. Probably this is another aspect of the same action; additional carbo-

MANURING, THE PRINCIPLES OF (*Continued*)—
hydrate leads to additional nitrogen fixation by the organisms in the root nodules, and this in turn to extra growth in warm weather and extra storage of food in the roots, to carry the plants over the winter.

Many other instances could be given where potassic fertilizers have increased the health and vigour of the plant, though whether this is always associated with excess of nitrogen is not definitely known. They usually act best in bad growing seasons, when unmanured crops are doing badly; they thus have a steadying effect on yields. They enable the plant also to withstand fungus pests, or perhaps it would be more correct to say that they counteract the effect of excess of nitrogen in predisposing the plant to attack. With excess of nitrogen and no potassium, mangolds at Rothamsted are liable to attack by *Uromyces Betæ*; barley at Woburn by *Fusarium culmorum*; tomatoes at Cheshunt by " streak " disease and " blotchy " ripening; all these liabilities are reduced by potassic fertilizers. (See Glasshouse Crops.)

Potassic fertilizers appear to facilitate the uptake of water by plants; they have proved useful in seasons when spring is dry, and they tend to keep cereals and grass standing up well; at Rothamsted the grass receiving potash stands up better than adjoining grass receiving none. Potassic fertilizers also influence grain formation.

Serious shortage of potash affects the leaves, causing them to become lighter and duller in colour, finally to die at the tips and edges; they look as if they had been scorched. Instances are sometimes seen in the North of Ireland on flax. (See Flax; also Fruit Plants, Manuring of.)

Phosphatic Fertilizers—The usual phosphatic fertilizers are superphosphate, by far the commonest in use, basic slag, and, in much smaller amounts, bones and ground mineral phosphate. Phosphates have much less effect on the leaf than either nitrogen or potassic fertilizers; their most striking action is on root or tuber formation, and for this reason they are chiefly used in England for potatoes (Table II.) and swedes. They also, however, have a marked effect in increasing the tillering of cereals. Plants inadequately supplied with phosphate, therefore, have a poor root system (especially the storage root or tuber), and cereals do not tiller well. When the shortage of phosphate is more pronounced, ripening of cereals is delayed; the phosphate-starved barley at Rothamsted is about ten days later in ripening than the adjoining crop receiving superphosphate. This hastened ripening by the use of phosphatic fertilizers has been demonstrated in the North of Ireland by Scott Robertson, where the difference amounted to about a fortnight, a very important result, since harvests are often late and hampered by bad weather. On no soil yet studied, however starved of phosphate, is any effect produced on the proportion of grain to straw. On the Rothamsted barley plots supplied with nitrogen and potassium fertilizers, but no phosphate, the grain formed 45 per cent. of the total produce during the first ten years of the experiment (1852-1861), and almost exactly the same proportion (44·7 per cent.) during the fifth ten years (1892-1901)

MANURING, THE PRINCIPLES OF (*Continued*)—

when phosphate starvation was very pronounced. (See Fruit Plants, Manuring of.)

Easily soluble calcium phosphate has the remarkable effect of facilitating or hastening the change of the nodule organism from a non-motile to a motile condition, and so increasing the chance of its getting into the roots of clover or lucerne and forming the nodules necessary for good growth. Phosphate is therefore used with great advantage in grass land for the encouragement of clover, especially wild white clover (*q.v.*) where this is able to grow.

Phosphate starvation is not so quickly recognized as nitrogen starvation. In extreme cases swedes and turnips fail altogether, the leaves of cereals become dull greyish-green in colour, while those of apple trees are bronze coloured, and are carried mainly at the tips of the shoots. Long before this stage is reached, however, the crop yields have suffered without showing why. By the time the phosphate starvation is detected it may be too late to cure it. Plants (cereals at any rate) take up their supplies of phosphate in the early days of their growth, and gain little or nothing from phosphate supplied later on.

Scott Robertson finds that the most sensitive crops to phosphate starvation are swedes and turnips; next come potatoes, next are oats, and the least sensitive is hay. The returns given by superphosphate in his experiments on phosphate-starved soils of Northern Ireland were, when the yields without phosphate were put at 100:

	No Phosphate.	*Superphosphate.*
Turnips	100	736
Potatoes	100	209
Oats (second crop)	100	171
Hay (third crop)	100	118

Phosphate deficiency may occur on any type of soil, and its effects are as harmful on any one soil as on any other.

Phosphate deficiency is common in many parts of the world, lowering the crop-producing power of the soil when it is in arable cultivation, and causing "deficiency diseases" in animals grazed on the natural herbage.

In England instances occur on the heavier loams of Suffolk, well demonstrated at Saxmundham; the acid Pennine Millstone Grits of Cheshire and the north of England, and the Oolitic soils of Gloucestershire and Oxfordshire. The fen soils of East Anglia respond notably to superphosphate, as also do many of the glacial soils.

Some of the most striking examples of phosphate-deficient soils are found in the Empire, and on these superphosphate has had remarkable effects. The classical instance of improvement of wheat soils by superphosphate are those of South Australia, studied for many years at the Roseworthy Agricultural College. (See Agriculture, Australia.) Phosphate-deficient pastures are found all over the Empire, in New Zealand, Australia, and South Africa; very striking improvements have been effected by the use of superphosphate or of slag. The

MANURING, THE PRINCIPLES OF (*Continued*)—

deficiency diseases of animals fed on the phosphate-starved herbage have been studied in great detail by Arnold Theiler and his colleagues.* The affected animals devour bones with great eagerness, even putrefying bones, when the deficiency is pronounced, so that they become liable to a particular ptomaine poisoning. The obvious remedy is to supply calcium phosphate to the animal in the form of clean bone meal or in other ways; this is mixed with other mineral foods into a so-called " lick," of which a number are on the market as proprietary articles. Low quality of various crops is commonly associated with low phosphorus content, and this can to some extent be remedied by dressings of phosphate. (See Metabolism, Mineral.)

Many of the pastures of Great Britain, particularly those on clay soils, respond markedly to dressings of phosphate, especially basic slag; this encourages the wild white clover (*q.v.*), and so improves the type of herbage; the benefit of the improvement, however, is seen only when the grazing is efficient. If the herbage is not properly kept down by well-managed grazing, all the benefit of the slag may be lost.

It was at one time supposed that superphosphate made the soil acid; this is now known to be entirely incorrect.

Value of Solubility—There has been much discussion as to the value of solubility of phosphates. In comparative experiments, superphosphate usually comes out best, followed by high soluble basic slag; low soluble basic slag made from fluorspar, and ground mineral phosphate also of low solubility are still less effective. A new low soluble slag not made with fluorspar is being studied, and the effect of mineral phosphate is improved by fine grinding (see Fertilizers, Basic Slag). Plants vary, however, in their power of utilizing mineral phosphate; swedes and turnips can take it fairly readily; potatoes and mangolds are less able to do so; cereals still less, hay least of all. Although it is soluble in water, superphosphate does not easily wash out from soil, especially from heavy soil; any excess left over from one year is presumably available for the following years. Utilization of the phosphate, however, is never complete.

Organic Manures—There has been much discussion as to whether these have any value over the standard artificial manures. In the few experiments where comparisons have been made, they were no better; they were, of course, dearer. They have some advantages; they are not easily abused, and they are more fool-proof; but this does not explain why so many good practical men prefer them. The comparison is being repeated by the Rothamsted workers.

Other Substances—Plants require many other substances besides nitrogen, potassium, and phosphorus; usually these occur sufficiently in the soil, but in certain conditions they do not. Experts are gradually learning how to recognize the effect of these special deficiencies; lack of manganese causes a "grey fleck" or "grey spot" (*Dörrfleckenkrankheit*) disease of oats; lack of magnesium causes a special

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* A. Theiler, H. H. Green and P. J. duToit, " Phosphorus in the Livestock Industry," *J. South Africa Dept. Agric.*, viii., 1924.

MANURING, THE PRINCIPLES OF (*Continued*)—

kind of yellowing of the leaf; lack of iron gives a dull colour and may affect the animals grazing on the herbage. The treatment of these soils is rather difficult, and farmers should consult the County Organizer before doing anything. E. J. R.

MARKET GARDENING—Vegetable Growing—The production of fresh vegetables on a commercial scale is an important and profitable industry in all countries, such as Great Britain, possessing large urban populations. As transport has always been an important factor in this industry, market gardening has tended to develop most freely in the neighbourhood of the cities and large towns in which the produce is to be consumed, but in recent years the development of motor transport and improved railway facilities have assisted in the development of districts which, while possessing soil and climate eminently suited for the purpose, are nevertheless remote from the markets they serve. At the present time, therefore, it may be stated that, provided there is a sufficiency of the suitable type of labour, soil and climate are the two most important factors to be considered. The soil suitable for the successful cultivation of most market garden crops must be of the type which can be freely cultivated throughout the year, and should belong preferably to the category of "early land." The climate must be equable—not subject to extremes of heat and cold, particularly the latter. The market gardening districts of England bear out this statement. The chief producing areas serving London are located mainly on the sandy loams derived from the Greensands, Alluvium, and Brickearth in the counties of Kent, Middlesex, Bedford, Surrey, Sussex, and Essex. Some of these areas possess a double advantage in that, in addition to a "warm," suitable soil, the influence of the seaboard and abundance of sunshine all combine to produce the highly desirable "early" districts so much sought after by vegetable growers. The Alluvial belts of the Thames Estuary (the Kent and Essex shores), and the Brickearth belt of the west Sussex seaboard are examples.

The acreages devoted to certain vegetable crops grown mainly for human consumption in 1930 are stated in the Agricultural Returns of England and Wales, 1930 (*J. Min. Agric. and Fish.*, Sept., 1930), to be as follows:

Cabbage	30,800 acres.	Onions	2,000 acres.
Brussels sprouts	26,500 ,,	Green beans	13,500 ,,
Cauliflower and broccoli	14,900 ,,	Green peas	56,000 ,,
Carrots	9,100 ,,	Rhubarb	7,700 ,,
Celery	6,400 ,,		

The need of a rapid and effective means of transport was referred to above. Most vegetables are consumed in a fresh condition, which for many of them is also a perishable condition, and crops must be delivered to the consumers within twelve or twenty-four hours of gathering, or they will deteriorate in quality and consequently in selling value. Good roads, in the case of motor transport, and good

MARKET GARDENING (*Continued*)—

railway services are, therefore, fundamentally essential for the industry. (See Marketing.)

A few words should be said on the subject of the production side of the market gardening business. The successful management of market garden land and the raising of profitable crops of vegetables is a highly skilled art. A good market gardener rarely has his land lying idle for any length of time, and it is a common practice to take two, and sometimes three, crops from it in a single year.

A most important matter to the vegetable grower is the subject of strain in varieties. Although most striking improvements have been made in recent years in varieties of vegetables by selection, it must be admitted that the principles of scientific breeding have rarely, if ever, been applied to their production. (See Mendelism.) Most of our "varieties" of vegetables are in a genetically mixed condition, and although the rigid mass selection to type practised by many large seed growers tends to maintain these collections of heterozygous forms of which most varieties consist in something approaching uniformity, the crop grower is always exposed to the risk of acquiring either a thoroughly bad or an indifferent strain of the variety of vegetable he desires to cultivate. Selection cannot do more than isolate and preserve desirable forms, which occur either spontaneously as mutations or as the result of the crossing of heterozygous forms; it can play no part in their creation. The only safe and reliable method of maintaining pure stocks of vegetables is by making sure that the initial selection is a homozygous form or a pure line. This presents no great difficulty in the case of self-fertile individuals, but, unfortunately, this condition is not always found in our vegetables, notably the Brassica Family. Not that selection will ultimately no longer be necessary. As all scientific breeders will admit, selection will still continue to play an important part in keeping the stocks pure and true to type. It is satisfactory, therefore, to find that scientific plant breeders are now turning their attention to vegetables, and their work in breeding out the pure line forms, followed up by carefully planned hybridization, may in the end confer a lasting benefit on the market gardening industry. (See Vegetable Breeding.)

ARTICHOKES—Two distinct plants are grown as vegetables for human consumption under the name of artichoke. The true artichoke (*Cynara Scolymus*) is commonly known as the Globe Artichoke to distinguish it from the Jerusalem Artichoke, although in appearance neither plant has the slightest resemblance to the other. Both, however, are members of the Compositæ family, but whereas the Globe Artichokes are cultivated for the sake of their fleshy, immature flower heads, which are boiled and eaten, the Jerusalem Artichoke, a member of the Sunflower genus of plants, is grown for the tubers which are formed below ground in the same manner as potatoes. This plant is said to have received its name of artichoke because the flavour of the tuber when cooked resembles that of the true, or globe, artichoke. And although commonly assumed to have some connection with

MARKET GARDENING (*Continued*)—

Jerusalem, actually this is not the case, the name having come into use as a corruption of the Italian name *girasole*.

The Globe Artichoke (*Cynara Scolymus*)—A native of southern Europe, this plant is not sufficiently hardy for general cultivation in the British Isles, although as a market garden crop it is found in the southern counties of England, particularly in Middlesex and parts of Kent and Surrey, on light, sandy loams in which the crop thrives best. Although not so generally esteemed as a vegetable in the British Isles as on the Continent, where it is very popular, the globe artichoke meets with a fair demand in London and other large cities, and it is noteworthy that considerable quantities are imported from France and Italy to augment the home-grown supply.

This artichoke thrives in a deep, sandy loam and in an open situation. It is propagated by the suckers which spring up each year from the base of established plants. These suckers being attached to the parent stool should be carefully detached with a "heel," and in market garden practice they are usually set out with a dibber in clumps of three, about 9 ins. apart, and at a distance of 3 ft. from clump to clump. The rows of clumps should be about 5 ft. apart to allow for horse cultivation. Planting is done in April, prior to which the land should receive a heavy dressing of stable or farmyard manure. Deep cultivation is also important.

A few heads may be obtained in the autumn of the year of planting, but the main cuttings will come on in the following year. With care and attention the plants will continue in a good bearing condition for several years, but to preserve a continuity some new planting should be made annually. As a rule, a plantation is grubbed after the fifth year.

The plants are tender and liable to injury by frost. To guard against this they should be protected after the month of November by packing dry litter, leaves, or bracken around them, removing the protection towards the end of March.

When taking suckers for replanting care should be exercised to see that two or three of the strongest are left on the plant to increase the bearing capacity of the stool.

Artichoke chard is the name given to the blanched central leaves of the plant which are obtained from worn-out plantations prior to their grubbing.

The chard sells less readily in the British Isles than on the Continent, where, used like Cardoons, it is regarded as a delicacy.

The varieties of globe artichoke most usually cultivated in Great Britain are known as **Globe, Common Green,** or **French** and **Purple,** the first named yielding the largest heads.

These artichokes appeal to the epicurean taste, and as good prices are invariably realized for the crop, there is no reason why its cultivation should not be extended where conditions are favourable.

The Jerusalem Artichoke (*Helianthus tuberosus*)—The value of this crop plant lies in the fact that, in addition to being a fair substitute

MARKET GARDENING (*Continued*)—

for the potato, it is much hardier in nature, and may be grown successfully on even the poorest of land. It is a tuberous-rooted member of the perennial Sunflower class of plants, but it very seldom flowers in the British Isles. It is thought to be a native of Brazil.

In nutritive value the tubers are about equal to the potato, but in composition there is a marked difference, simple starch being absent and the carbohydrates being represented by the substance known as inulin. (See Feeding Stuffs; Carbohydrates.)

While this artichoke may be grown in almost any soil and situation, the tubers scatter so freely that in only the lighter, sandy soils is it possible to clear the crop from the land. To obtain the maximum yields of tubers the land should be well manured, but quite good crops may be grown after a crop manured in the previous year.

Planting is carried out by means of small, whole tubers or pieces of large ones which are set out in prepared trenches, or they may be dibbed in 15 ins. apart with 30 ins. between the rows, which should run north and south. A dressing of from 3 to 5 cwts. of superphosphate and 1½ cwts. of sulphate of potash, per acre, will improve the quality of the crop.

About 10 cwts. of small tubers are required to plant an acre, and a yield of 10 to 12 tons per acre is regarded as satisfactory. Very little cultivation is needed by the crop, as the plants soon cover the ground and prevent the growth of weeds. The tubers are lifted during October or November and may be stored in clamps until ready for sale.

ASPARAGUS (*Asparagus officinalis*)—This profitable market garden crop may be grown on most soils, but the most suitable for raising high-class produce are sandy loams and alluvial soils, because they supply good aeration, drainage, and other conditions which make for earliness, quality, and ease of cultivation. As the crop will occupy the same piece of land for twenty years or more, thorough preparation at the outset is essential.

Light land should be very deeply worked, and receive from twenty to thirty loads of manure per acre. Calcareous matter, ground chalk, or basic slag (10 to 15 cwts. per acre) should also be worked in at the time of preparation, which is always better if carried out in the autumn, allowing the land to lay rough through the winter.

Planting—Asparagus may be grown in single rows about 3 ft. 6 ins. apart, with the plants about 1 ft. apart in the rows, or in beds either 4 ft. 6 ins. or 3 ft. wide, the former taking three and the latter two rows of plants. The best results are obtained by employing one-year-old crowns, raised from seed, and planting takes the form of setting them out in channels not less than 3 ins. deep. A good hoe may be used for this purpose, but in the Evesham district a "channeller," consisting of an equilateral triangle of steel fitted to a long handle, is especially employed. The crowns are laid on their sides and the planter covers them firmly with soil as he goes, or if

MARKET GARDENING (*Continued*)

very small they may be dibbled in. Care should be taken that the crowns do not get unduly dry during planting.

Varieties—Productive varieties are **Connover's Colossal, Palmetto, Argentaill Giant Purple,** and **Giant Dutch,** but the variety most grown in the Evesham district is **Bedinham's Purple Giant,** probably a sport from Connover's Colossal. Local and private strains are, however, common.

Cultivation consists of keeping down weeds, top dressing the beds with well-rotted manure, and covering them with about 2 ins. of soil, taken from the alleyways, each autumn. When beds are in full bearing, manure should be applied at the rate of 12 tons to the acre, supplemented with from 4 to 6 cwts. of superphosphate, and 1½ cwts. of sulphate of potash. A useful spring dressing is 4 cwts. of nitrate of soda, or 10 cwts. of old soot, to the acre.

The crop should not be taken from newly established beds until the third season from planting, and for the first year or two cutting should be ceased earlier than usual in order to establish the crowns, and build up the beds. The longevity and productivity of the beds will depend on how they are handled during the first few years. Cutting usually commences about mid-April and lasts until about the third week in June.

Marketing the crop requires care. All cuttings should be carefully graded in a cool shed, using first, second, and third grades. The buds are "scored," or tied, in bundles of fifteen or twenty, and retied again in bundles of eight of the fifteen counts and six of the twenty counts, which are known in the trade as "hundreds" (120 buds). A bundling machine and a "scoring" box are indispensable to the large asparagus grower, and he must learn how to prepare his produce attractively. Special bundles are sometimes made of early cuttings or of buds of exceptional quality.

Insect Pests—The chief pest is the asparagus beetle (*Crioceris asparagi*), which in both the larvae and adult stage devours the heads as they are formed. It can, however, be controlled.

Diseases: *Asparagus Rust* (*Puccinia asparagi*)- This disease has occurred in England, but in the United States it became a serious disease of asparagus soon after its introduction to that country.

All spore forms are produced on the stems and needles, and occur in small reddish pustules, which become darker in colour towards the end of summer. Clouds of spores are given off when affected asparagus plants are shaken, and these serve to disseminate the disease. Re-infection in the following spring is caused by the sporidia produced from the teleutospores which germinate after over-wintering.

Another affection of asparagus is sometimes called "rust" by growers. This can hardly be called a disease, and is characterized by reddish, streaky discolorations of the blanched underground part of the grass at cutting time. Nothing is yet known as to the cause of this trouble.

MARKET GARDENING (*Continued*)—

Little can be done when a serious outbreak of this disease occurs, but it is a wise precaution to gather and burn all diseased shoots. Some varieties of asparagus are comparatively resistant to the disease, and the best means of prevention is by the selection of resistant varieties and the avoidance of overcrowding.

REFERENCE.—W. B. Grove, "The British Rust Fungi," Camb. Univ. Press, 1913. H. H. S.

BEANS, GREEN—Three members of the bean family are cultivated for consumption in a green or unripe condition, and all of them are important market garden crops. The area devoted to the cultivation of green beans in England in 1929 was 12,611 acres, the chief centres of production being the counties of Kent, Middlesex, Essex, Bedfordshire, and the Evesham district of the west Midlands. These beans are the broad beans (*Faba vulgaris*), the dwarf or kidney bean (*Phaseolus vulgaris*), and the scarlet runner bean (*Phaseolus multiflorus*). The most important in the commercial sense is the scarlet runner bean, and it is invariably the one principally grown for market.

(1) **Broad Beans**—Of the several forms of this bean only two hold an important place—the broad-podded or Windsor type, and the long-podded type. Good varieties of the former type are **Broad Windsor, Green Windsor,** and **Green Harlington,** and of the latter **Seville Long-pod, Bunyard's Long-pod,** and **Johnson's Long-pod.**

Cultivation—Broad beans require a deep, well-drained, strong loam, and the normal practice is to follow a previously well-manured crop. Phosphates are, however, an important plant food, and an application of 4 cwts. of superphosphate per acre, or other form of phosphate, according to the character of the soil, ensures profitable returns. This crop can be grown by sowing the seed in the open ground either in November or early December (in which case the plants are expected to stand the winter), or from early February to end of March. The **Seville Long-pod** is the variety generally employed for autumn sowing, Spanish seed giving earlier crop than the French. The plants should be from 4 to 5 ins. apart, and the rows 2 to 2½ ft. apart, about 4 bushels of seed being required per acre. (See Beans.)

Marketing—The first crop of broad beans should be ready for picking in June, and the bulk of the crop in July. A fair yield of the early **Seville Long-pod** would be from 5,000 to 6,000 lbs. of pods per acre, and twice this quantity for other varieties. The beans are sent to market in bags or "pods" containing 40 lbs.

(2) **Beans, Dwarf or Kidney**—This is one of the edible podded type of beans, and although rarely grown as a single crop for market, it is extensively used in some districts for intercropping between rows of young asparagus, cauliflowers, and some of the bush fruits when in their young stages of growth. This bean is also used in England for forcing under glass, for which good prices are usually realized.

MARKET GARDENING (*Continued*)—

Varieties—Good varieties of this bean are: **Early Prolific** (a very early variety), **Pale Dun, Masterpiece,** and **Canadian Wonder.** The variety used for canning is a stringless form named **Refugee.**

Cultivation—A light, loamy soil which has been previously manured will suit this crop best. Owing to its extreme susceptibility to cold, this bean should not be sown until the end of April, continuing for succession until the middle of May. Suitable distances for the plants are from 10 to 12 ins. apart, and from 20 to 24 ins. between the rows. About ½ bushel of seed is required to sow an acre of land, and two-year-old seed is regarded as being better than new.

Marketing—Dwarf beans of the edible podded type should be picked while they are still tender, and the frequent picking over of the plants will keep them in a prolonged bearing condition. The beans are usually sent to market in hampers containing 40 lbs., and they generally sell better in the north than in the south of England.

(3) **Beans, Runner**—Although a climbing form of bean and cultivated as an annual, the runner bean is really a perennial plant with thick, fleshy rootstocks. Being of tender constitution, however, it seldom survives a northern winter, and in any case, for commercial purposes, it is always resown every year on fresh land. Like the dwarf bean, it is an edible podded type, and is grown exclusively for the sake of its succulent green pods.

Varieties—Good varieties for market are: **Scarlet Emperor, Ne Plus Ultra, Sutton's A 1.**

Cultivation—The soil conditions described above for dwarf beans will suit the runner beans also. Although a limited area of this bean is grown on sticks, by far the largest area is grown without sticks, the climbing habit of the plants being kept in check by frequently pinching out the growing shoots, commencing when the plants are about 6 ins. high. In this way compact, bushy plants are formed, provided they are gone over every week, and the yield of beans therefrom is usually very heavy.

The seed is usually planted by hand, 4 or 6 ins. apart, in rows 30 to 36 ins. apart. The plants are ultimately thinned out to 9 or 12 ins. apart. A little over 1 bushel of seed should plant an acre of land.

Although beans thrive best when following a well-manured crop, it has been found that they always respond to applications of phosphate and potassic fertilizers applied to the soil at planting time. Soot and Peruvian guano are also beneficial. Nitrogenous manures should be carefully used.

Marketing—A good field of runner beans should produce about 12,000 lbs. of pods per acre in a season, the crop usually commencing about the end of July. The first pickings are generally sent to market in hampers of 40 lbs., but later in the season bags are often used.

Disease: *Chocolate Spot of Beans* (*Bacillus lathyri*)—In most years bean crops are slightly affected with this disease. Occasionally, as in the year 1926, the disease assumes epidemic proportions and causes serious losses.

MARKET GARDENING (*Continued*)—

The characteristic sign of the disease is the presence of chocolate-coloured spots or blotches on the leaves and stems. In advanced cases of attack, the plants may be defoliated and the flowers drop off, thereby ruining the crop. It is very doubtful whether all the chocolate-coloured spots on beans are due to *B. lathyri*; some of them may be caused by cold winds and frost in early spring, and others to aphis exudates. The same organism has been found to be the cause of Streak Disease of sweet peas and clover, and Stripe of tomatoes. (See Glasshouse Crops.)

As a rule, a soft type of growth favours the disease, while a hard form of growth tends to inhibit it. Experiments on "streak" disease of sweet peas and "stripe" of tomatoes have shown that the disease can be much reduced by manuring with sulphate of potash at the rate of about 5 cwts. per acre. It is possible that some similar soil treatment, such as the application of basic slag, which would tend to release potash in the soil, would be valuable in preventing "chocolate spot" in beans.

REFERENCE.—S. G. Paine and M. S. Lacey, "Streak Disease of Broad Beans," *Ann. App. Biol.*, vol. x., p. 194, 1923. H. H. S.

BEETROOT (*Beta vulgaris*)—Some varieties of beetroot are grown for human consumption, but as they are used almost entirely as a salad vegetable the consumption is not considerable, and the annual area under the crop is never very large. Considered as a market garden crop, however, it is usually profitable to cultivate, and, in view of the fact that the beetroots may be safely stored for several months, it can be stated that it is by no means speculative. On the other hand, fields of beetroot, like carrots, parsnips, and onions, are fairly expensive to cultivate. These root crops may easily cost up to £20 per acre to grow, most of which is absorbed by the labour side of the undertaking.

Varieties—All beetroots grown for human food are of the coloured forms, and the various varieties range in colour from a bright red to a deep purplish red; and three distinct shapes are known—viz., the turnip-rooted, the oval-rooted, and the long-rooted forms. For early crops the turnip-rooted varieties such as **Red Globe** and **Egyptian Turnip-rooted** should be grown. For second early crops, good market varieties are **Feltham Intermediate** and **Nonpareil,** both oval forms, and for the main crops **Cheltenham Green Top, Covent Garden Red, Nutting's Dwarf,** and **Dell's Crimson,** all long forms.

Soils suitable for the beetroot and the general lines of cultivation follow closely those advised for the carrot crop. No farmyard manure should be applied to the land, but a dressing of 2 cwts. of sulphate of potash and 4 cwts. of superphosphate will be very beneficial to the crop. The early crops should be sown at the end of April, and the main crops in the first fortnight of May.

Marketing—The earliest are usually bunched in dozens and half-dozens, and the main crops are sold by weight. In both cases the roots

MARKET GARDENING (*Continued*)—

should be graded and washed clean, and special attention should be given to packing to guard against bruising, with its resultant "bleeding," which causes a loss of colour in the root when cooked. A good crop would fall between 6 and 10 tons to the acre according to the variety grown. The crop is liable to frost damage, and should be lifted and stored by Christmas.

CABBAGE FAMILY—Genus Brassica—The cabbage family, all forms of the natural species *Brassica oleracea*, provides some of the most important market garden crops now in cultivation. The natural species from which these diversified cultivated forms—the green cabbage, the savoy cabbage, the cauliflower, the broccoli, the brussels sprout, the kale, and the kohl rabi—are derived is still to be found growing wild on cliffs and rocky coasts of Northern Europe.

The cultivator of these forms of cabbage must not lose sight of the fact that the Brassica crop must not be grown too frequently on the same land, and any one form of cabbage should not follow another on the same land, until at least two clear years have elapsed. The commercial grower is, therefore, frequently limited in the amount of the cabbage family he can produce annually.

Another noteworthy point is that, owing to the freedom with which all forms of the family can intercross, seed strain becomes a very important matter, and may often make all the difference between a good profit and a substantial loss. Cheap unreliable seed, therefore, should always be avoided. (See Brassicæ, Morphology and Genetics of.)

Broccoli (*Brassica oleracea botrytis asparagoides*)—(1) Heading Type—A cultivated variety of cabbage which is grown for the sake of its condensed, fleshy, compact inflorescence, known as the curd. On account of its hardiness the crop's season is different from that of the more tender cauliflower, which it closely resembles, and consequently it is always in good demand. When well grown it is almost invariably a profitable crop.

Remarkable changes have taken place in the broccoli-growing industry in recent years. These changes, involving the introduction of better varieties and of improved methods of marketing, have secured an all-round higher selling value for the crop. The Roscoff type of broccoli, which was introduced from France in 1923, is now universally recognized as the most important form for commercial cultivation. The varieties of this type furnish curds of greater uniformity, better colour, and finer flavour than the old types, the one drawback at present being their degree of hardiness. They are not so successfully grown in colder climates as some of the older types. The work of the Gulval Experimental Station, Cornwall, in seeding, selecting, and distributing to English growers the various strains of the Roscoff type, has conferred a benefit on the industry, and the attention of scientific plant breeders should doubtless result in the evolution of hardier forms of this eminently desirable type.

The limited capacity of the crop to withstand winter injury accounts

MARKET GARDENING (*Continued*)—

for the chief producing areas being localized in the warmer parts of the country, notably the south-western and south-eastern counties. Cornwall possesses the largest acreage devoted to the crop, and about 15,000 tons of broccoli are despatched from the different districts of that county every year. The total acreage devoted to the cultivation of broccoli and cauliflower in 1929 was returned at 13,863 acres, the division being about equal.

Varieties—The **Roscoff** type is capable of supplying a range of varieties to give a satisfactory succession of cutting from the end of November to the end of March. Of the older types the following are of established commercial reputation, and also possess the advantage of being of hardier constitution: **Winter Mammoth**—October to November. **Late Protecting**—October to November. **December**—October to December. **Mammoth**—November to December. **Early White**—January to February. **Superb Early White**—January to February. **Snow White**—February to March. **Favourite Late**—March to April. Climatic conditions, however, tend to advance or retard the seasons.

In broccoli growing, the importance of strain cannot be over-emphasized, and for that reason only the very best strains of seed, saved by reliable seed growers, should be purchased. The broccoli plant, like its prototype the cabbage, is subject to a great amount of inherent variation, and if the fact that it will readily cross-fertilize with other varieties of Brassicæ is considered, it will be realized how great is the risk of rapid degeneration in any given stock unless proper precautions are taken in seed saving. This point is stressed as the difference between profit and loss on the crop depends, considerably, on securing a field of uniform, high-grade plants. A grower, therefore, should not succumb to the temptation of saving his own seed unless he is able to select to type and to adopt proper precautions against cross-fertilization. On the other hand, a careful grower who understands the principles of seed raising may often not only raise his own seed, but with care and foresight may even effect considerable improvement in individual strains. (See Vegetable Breeding.)

Cultivation—Except that the crop does best in fresh land—that is, land that has not grown a cabbage crop for some years—the principles of cultivation which extend to all the Brassicæ crops apply equally well to broccoli. The grower should, however, apply nitrogenous manure carefully where there is any risk of severe winter conditions, as soft, sappy growth will always suffer most. It is a common practice to follow early potatoes with broccoli, but evidence has been obtained to prove that the crop will do better and be more profitable when treated as a main crop following potatoes, roots, or a cereal. Generally, the residuum of manures from the previous potato crop, with the aid of fertilizers, is sufficient to carry a crop of broccoli, but if the broccoli follow a cereal or a fallow, from fifteen to twenty loads of well-rotted farmyard manure should be applied to the land some months previous to planting. Kainit and superphosphate are usually beneficial, pro-

MARKET GARDENING (*Continued*)—

moting both resistance to climatic injury and disease and improving the quality of the curd. Lime, also, will promote healthy growth, and tends to ward off leaf dropping and club-rot disease. Applications of a nitrogenous fertilizer as a stimulant during the growth season are often beneficial, but need not be considered very carefully in the light of individual circumstances. At planting time the land should be well rolled to ensure firmness, an important condition.

Rows should be from 2½ to 3 ft. apart, with the plants 2 ft. apart in the rows; these distances permit of horse cultivation.

Marketing—The old wicker "pots" and broccoli nets have now given place to the non-returnable wooden broccoli crate, holding eighteen or twenty-four heads. Growers find the crop more profitable when they grade and pack it themselves, instead of selling at a fixed price per acre to a salesman or a dealer as is often done. The proper grading and trimming of the heads is very important, and all discoloured, broken, and rough curds should be rejected. In packing the crates arrange the heads in layers with the stems pointing outwards, and a well-packed crate should be just over brimful to ensure a tight package when the lid is on.

REFERENCES: H. W. Abbiss, "Broccoli Trials in Cornwall," *J. Min. Agric.*, March, 1925; H. V. Taylor, "A French Broccoli Packing Station," *ibid.*, June, 1924.

(2) Sprouting Type—These are distinct types of broccoli characterized by their habit of forming numerous small inflorescences, instead of one compact head. These types are very late in maturing, and as they usually come in when other vegetables are scarce, the crops of them are generally profitable. The culture follows similar lines to those advised for the "Heading" Type, except that being hardier they can be grown almost everywhere. They also require somewhat richer soil. There are two varieties, **Purple Sprouting** and **White Sprouting**, and there are early and late forms of each.

Cauliflower (*Brassica oleracea botrytis cauliflora*)—This fine and very popular vegetable resembles the broccoli in appearance, but differs from it in being less hardy, of superior flavour, and more generally attractive. The consumption of this vegetable is considerable, and large areas of land are devoted to its cultivation in the neighbourhood of London (Kent, Herts, and Middlesex), while other large producing areas are the Evesham, Biggleswade, and Wisbech districts. In the latter district, large quantities of special varieties of cauliflowers are grown for the pickling trade.

Although the cauliflower crops may be divided into two sections—viz., the spring sown and autumn sown—the former is by far the most important from the point of view of commercial cultivation. The seed of the spring-sown crops, which come in use during late summer and autumn, should be sown for succession during March and April preferably, and, in any case, not later than the first week of May. The plants from this sowing are set out as soon as they are large

MARKET GARDENING (*Continued*)—

enough, the secret of successful cultivation turning on the grower's ability to maintain continuous growth from start to finish. If the plants receive a check, the results will be revealed either in "buttoning," *i.e.*, the early formation of small unsaleable heads, or "bolting," *i.e.*, running to seed. The seed of the autumn sown crop is usually sown during August or early September, and the plants so obtained are set out in frames or cold greenhouses, where they remain for protection during the winter, until the following spring, when they are planted out, after all risk of frost has gone, and usually mature during June and July. The plants are sometimes wintered in small pots.

While the general methods of cultivation are on lines similar to those advised for broccoli, they differ in detail. In the first place, the cauliflower is a gross feeder, and good crops can be grown only when the land has been liberally manured with farmyard or stable manure. In some of the districts supplying the London market, as much as thirty loads per acre of this manure is applied, but the type of soil chosen for the crop should be considered when dealing with the question of manurial treatment. Secondly, to avoid the fatal checks to the plants already referred to, deep ploughing, followed by frequent cultivation after planting, is necessary to promote active growth and conserve soil moisture.

A good marketable cauliflower should be compact in appearance, quite white in colour, and from 6 to 9 ins. in diameter. During the time the crop is maturing, a frequent inspection of the plants should be made, and all exposed heads that are not yet fit for cutting should have the large outer leaves broken over them for protection against the discolouring effect of the sun. Cauliflower for market should be cut either first thing in the morning or late in the evening when the dew is on them. This will add considerably both to their edible quality, and to their period of freshness. Packing follows the lines laid down for broccoli.

Varieties—Good profitable varieties are: **All the Year Round, Early London, Eclipse,** and **Early Erfurt,** for autumn sowing; and **All Saints, Autumn Mammoth,** and **Veitch's Autumn Giant** for spring sowing. Varieties suitable for the pickling trade are: **Danish Giant, Danish Export, Early Erfurt,** and **Erfurt Dwarf,** and these, being smaller, may be grown closer together than the other types.

In common with all other members of the Brassica family, and for identical reasons, the question of the strain of the seed is supremely important.

Cabbage, White (*Brassica oleracea capitata*)—The white cabbage is a very important market garden crop, and in the area annually devoted to its cultivation is probably the third largest, potatoes and green peas taking first and second place respectively. The area under cabbage grown for human consumption in 1930 was 30,800 acres.

It is very accommodating as regards soil, and within the two chief sections comprising the white cabbage group, varieties possessing a

MARKET GARDENING (*Continued*)—

range of hardiness sufficient to provide useful cutting periods throughout the year may be found.

The two chief sections of the group are: (1) the varieties possessing pointed or heart-shaped heads—the spring and summer cabbage, of which **Ellam's Early** is an example; and (2) the varieties possessing round flattish heads—the autumn and winter cabbage, of which **Primo** is an example. The first section may be again divided into (*a*) spring and early summer varieties, and (*b*) late summer and early autumn varieties. The remaining small section of the white cabbage group are those varieties classed as coleworts, which possess the feature of extreme hardiness and produce small heads which are not so compact as those of the other sections.

Varieties—The best market varieties are:

For spring and early summer cutting: **Harbinger, Early Market, Ellam's Early,** and **Myatt's Early Offenham.**

For late summer and early autumn cutting: **Winningstadt, Enfield Market, Nonpareil,** and **Leeds Market.**

For autumn and winter cutting: **Primo** (September to October), **Christmas Drumhead** (November to January); *Coleworts:* **Hardy Green** and **Rosette.**

The variety **Couve Tronchuda,** the *Portugal* cabbage, is remarkable for its tenderness and good quality. It was introduced from Portugal early in the nineteenth century, and although met with in gardens, it is not cultivated commercially in the British Isles. It does not form very compact heads, and as the variety is very tender, it is suitable only for summer culture. It is really the **Dwarf Portugal,** as there is also a large form of the type which grows about 2 ft. high and is much coarser in quality.

Here again it is necessary to emphasize the risk entailed by purchasing unreliable seed. Owing to lack of care in seed growing there are many mixed stocks in existence, and to secure uniform crops, true to type, the grower should obtain his seed only from firms who specialize in the production of cabbage seed. It is open to the grower, also, to save his own seed from selected plants. (See Vegetable Breeding.)

Cultivation—A deep, well-tilled loam, slightly on the stiff side, will suit the cabbage crop best, especially loams of the Brickearth, Alluvial, and Greensand formations. It should be worked into a rotation which will give at least two full years' interval between crops of any form of Brassica. Land intended for this crop must always be well manured, from twenty to thirty loads of farmyard manure being a usual dressing to ensure good results. The soil should be deep without a "pan" nearer to the surface than 15 or 18 ins. Useful fertilizers for the crop are fish guano, bone meal, or basic slag, which may be worked into the soil at planting time, at the rate of 5 cwts. per acre, and sulphate of ammonia or nitrate of soda, which may be cultivated into the growing crop at the least sign of nitrogen starvation, at the rate of 1½ cwts. per acre. The cabbage is a gross feeder, and a lack of nitrogen in the soil will result in "blueing" (a loss of green

MARKET GARDENING (*Continued*)—

colour in the leaves) and "bonyness" (tough, difficultly edible heads).

The range of cutting seasons quoted above indicates that cabbage growers must pay close attention to the question of raising plants. In ordinary commercial practice there are three distinct seed-sowing periods which must not be missed, the most important and the most crucial being that of the spring and early summer crop, which takes place at the time of year when it is difficult to obtain a moist, tilthy seed-bed. Experience has shown that the following is a safe time-table for sowing in the different parts of the country:

Eastern counties—23rd to 25th of July; Kent—end of July or early in August; Middlesex—1st to 5th of August; West Midlands—last week in July. The sowing for the late summer and early autumn crop should be made at the beginning of March, and for the late autumn and winter crop, during the last week of April or first week of May. The coleworts should be sown during the first or second week of May.

The seed is normally drilled on a firm seed bed $\frac{3}{4}$ in. deep, in rows 8 ins. apart, 8 lbs. of seed being enough for an acre. An acre of such a seed bed should furnish sufficient plants for from 6 to 8 acres.

Planting of the spring and early summer crop should commence by the third week of September, and be completed by mid-October. The late summer and early autumn crop should be planted during April, and the late autumn and winter crop during June. In districts where transplanting is difficult owing to low rainfall, the seed of the two last-mentioned crops may be drilled thinly in rows 2 ft. apart, and the plants are then spaced out with a hoe and left to mature where they stand. For transplanted crops the rows should be from 12 to 18 ins. apart, with the plants from 10 to 15 ins. apart, according to type.

Marketing—A maturing cabbage crop should have cuttings made twice a week, baskets, crates, bags, and coir nets being the recognized packages for market. The demand for white cabbage is usually good during March, April, and May, and from the middle of August until after Christmas.

Cabbage, Savoy (*Brassica oleracea Sabauda*)—This is a form of winter cabbage resembling the white cabbage, but with foliage characteristically crinkled. It will also resist frost more successfully; another point in its favour is that it will thrive on poorer soil than the white cabbage. In fact, when the land is too rich, savoys are liable to "splitting," and also tend to heart-in too quickly.

Good varieties are **Ormskirk, Best of All,** and **Drumhead.** The seed should be sown from the third week of April to first week of May, and the plants should be put out 18 ins. apart, with 2 ft. or 2 ft. 6 ins. between the rows.

In other respects the cultivation resembles that followed for white cabbage.

Cabbage, Red (*Brassica oleracea rubra*)—This is a similar form of cabbage to the white, except that it is of a dark-red or purplish colour throughout. The demand for it is limited, as it is used almost exclu-

MARKET GARDENING (*Continued*)—

sively for pickling purposes. Pickle manufacturers take a certain quantity of red cabbage every year, but growers are usually under contract. It is a robust, strong growing cabbage, which requires good, rich soil and plenty of room. Although it is the practice to sow the seed of this type during the autumn and transplant the plants in the spring, it can also be grown successfully by drilling the seed thinly in April and spacing out the plants where they stand with a hoe. Except that the rows should be spaced 30 ins. apart, the cultivation in general is on the lines laid down for white cabbage. (See Preservation, Fruit and Vegetables.)

Brussels Sprouts (*Brassica oleracea bullata gemmifera*)—This is another cultivated form of the cabbage family, its salient features being a thick, tall main stem which bears many large spreading leaves, at the axils of which the small, compact sprouts are ultimately borne. It is an extremely popular winter vegetable, and was grown commercially in 1930 to the extent of 26,500 acres. By far the largest producing area is the Biggleswade district of Bedfordshire, but large quantities are also produced in Worcestershire, Kent, Middlesex, and Essex.

Although the light, sandy soils of the Biggleswade district have become noted for the successful cultivation of brussels sprouts, the crop will thrive best on heavier loams, provided they are deeply worked and well drained. It is essentially a moisture-loving crop, and a little clay in the soil is appreciated. Also, lime should be present in the soil.

Varieties—Good varieties for the market are the **Wroxton, Standard, Aigburth,** and **Evesham Special.** Stocks of these varieties are, however, by no means uniform, and seed of good strains from reliable growers only should be utilized. (See Vegetable Breeding.)

Cultivation—Unlike most other members of the cabbage family, brussels sprouts do not demand heavy dressings of organic manure immediately prior to planting. The crop will thrive well if allowed to follow another crop, such as early potatoes, which was heavily manured. The most important point in cultivation is recognition of the fact that the crop requires a long season of growth, and when transplanting is adopted, early planting is the keynote of success.

There are two methods of cultivation: one being to sow the seed in seed beds in early March, and transplant the plants towards the end of May, the other being to drill thinly the seed in the autumn, leaving the plants to mature, after spacing out, where they stand. A suitable spacing for the plants in either case is from 2 to 2½ ft. apart, with 3 ft. between the rows. Overcrowding will reduce both the quality and the quantity of the crop.

Provided the land is in good heart from a previously well-manured crop, brussels sprouts maintain good growth with the assistance of the fertilizers advised for the white cabbage crop. In Bedfordshire it is the normal practice to apply 1 ton of soot per acre for this crop at the time of planting.

MARKET GARDENING (*Continued*)—

Marketing—Picking may begin as soon as the sprouts are ready, usually about the end of September, the usual method being to gather them as they mature instead of, as is practised in a few districts, cutting the whole plant down to the ground—a wasteful and undesirable method of marketing. The sprouts, being perishable, require to be marketed without delay, so that they arrive fresh and attractive. They are generally marketed in "half-bags" of 28 lbs., "pots" of 40 lbs., and half-sieves, and boxes holding from 14 to 20 lbs.

Borecole or Kale (*Brassica oleracea acephala*)—This form of cabbage is the most hardy and most easily grown of the whole family. Especially in hard winters when other forms are apt to suffer, the kales frequently prove very profitable crops, their surprising degree of vitality enabling them to withstand prolonged periods of intense frost. As the kales are capable of maintaining some rate of growth even during the winter, it is often profitable to sow the seed for succession, putting in the first batch early in March and a second about the middle of April. The best soil for the crop is a good-tempered chalky or clay loam. The plants should be set out 18 or 24 ins. apart, with at least 2 ft. between the rows. Under favourable conditions the plants will produce enormous crops of tender, succulent shoots during the first three months of the year, which are sent to market in bags containing a stated weight.

Good varieties for market are **Green Curled** or **Scotch Kale, Drumhead,** and **Asparagus.** The **Marrow-Stemmed** and **Thousand-Headed** (*q.v.*) are valuable varieties of kale, much grown as fodder crops.

CARDOON (*Cynara Cardunculus*)—The cardoon is another vegetable which, although popular and much esteemed on the Continent, is neither grown nor consumed to any great extent in Great Britain. It resembles chicory and seakale in that it is the blanched, succulent leaf stalks of the plant which are eaten after boiling. There is a demand for this vegetable during the winter months, especially from hotels and restaurants where French cooks, who know best how to prepare it for the table, are employed.

The varieties most generally grown are the **Spanish Cardoon** and the **Tours Cardoon.** The latter differs from the former in possessing long, sharp spines on the leaves which are apt to inflict injury unless carefully handled. The quality of the leaf stalks is, nevertheless, very good, and it is the variety most preferred in France. In England the Spanish Cardoon is most generally grown, and to a lesser extent another variety known as the red-stemmed cardoon.

Cardoons prefer a light, moderately rich soil and an open situation. In general outline the cultivation follows that practised for celery, all the varieties being raised from seed, which, owing to the fact that the plants do not transplant very successfully, is usually sown in shallow and well-prepared trenches during April. The plants will grow to a larger size than celery and should therefore be given more room. When sown in the open ground it is usual to drop a few seeds

MARKET GARDENING (*Continued*)—

in groups about 18 or 24 ins. apart, afterwards thinning out the plants to one when well established.

Unlike celery, no earthing up to blanch the plants is done until they are fully grown, which is usually from the first week of October onwards. The blanching is also a more elaborate process than with celery, as it is the practice first to gather up the plant's leaves to an upright position and tie with raffia, and then, before the soil is put up, each plant is carefully and closely bound up with haybands so as effectively to exclude both light and moisture. On a small scale blanching may be effected by slipping large drain pipes over the plants, afterwards filling the pipes with dry, sandy soil. The chief point to remember when blanching cardoons is that unless moisture is kept away from the hearts of the plants they will probably decay.

Cardoons are usually ready for use about three or four weeks after the work contingent on blanching is carried out; for market they should be perfectly blanched, crisp in texture, and free from discolorations and soil. When preparing the heads for market a few of the coarse outer leaves may be removed.

The heads are packed carefully in shallow wood trays, and the wholesale selling unit is usually a dozen heads, and retail by the pound weight.

CARROT (*Daucus Carota*)—The carrot is a vegetable of considerable economic importance, and commercially it takes first place in the group of root crops. In Great Britain the carrot is very popular in the towns of the Midlands and the North, where, especially during the winter months, the demand is usually a steady one with accompanying good selling values. In 1930 the area under carrots for human consumption in England and Wales was 9,100 acres, which indicates the economic position of the crop. One of the chief centres of production is the Isle of Axholme district of north Lincolnshire, where the deep sandy loams of the alluviums, or warped lands, in conjunction with a cool climate, are very suitable for the crop. Cheshire, Shropshire, and south-west Lancashire are other important districts for carrot production. The Fenland district of Chatteris in Cambridgeshire is also notable for its carrots.

Varieties—There are red, white, orange, and purple coloured carrots, but only the red varieties are grown for market. The carrot ranges in shape from the stump-rooted, horn types, through several gradations to the long-rooted, intermediate types, but the ideal carrot for main crop cultivation for market purposes is a bright coloured, long stump-rooted form possessing very little core. For early production in frames, or specially prepared carrot beds, only the short stump-rooted varieties, the horn carrot, are grown.

Good varieties for market are—

For early crops: **Early Scarlet Horn, Early Nantes, Manchester Table, Early Market.**

For maincrops: Long stump-rooted types—**Nantes, Chantenay,**

MARKET GARDENING (*Continued*)—

Altringham; Long-rooted or Intermediate types—**James's Intermediate, St. Valery, Long Red Surrey.**

For storing for long periods, *i.e.*, until late winter and early spring, the Intermediate types are the most suitable.

General Cultivation—Provided suitable soil conditions are available the cultivation of the carrot crop is a simple procedure. The soil should always be deeply worked and no fresh manure should be applied to the land, which should, however, have been brought into a high state of fertility through the treatment accorded the previous crop. Sandy loams, pure silts, and peaty silts are all ideal soils for carrots. Old soot applied just before sowing is a very suitable manurial dressing, and from 5 to 6 cwts. of superphosphate and 2 cwts. of sulphate of potash per acre will generally prove very beneficial to the crop if worked into the land at the final cultivation.

The seed of early carrots may be sown from the middle of March to the middle of April. Early crops are generally sown broadcast on specially prepared beds about 4 ft. wide, but the main crops are drilled in rows from 10 to 16 ins. apart according to the variety. The seedlings are thinned to 3 or 4 ins. apart.

Marketing—As most markets prefer washed carrots, growers of large acreage find it expedient to provide a carrot-washing plant, for which a plentiful supply of water is necessary. The carrots, which should be graded into sizes, are usually marketed in half hundredweights and hundredweights.

CELERY (*Apium graveolens*)—This crop is of considerable commercial importance to market gardeners and farmers in districts where the land is suitable. The peaty soils of Lancashire and Cheshire, the silty and "skirt" soils of Lincolnshire, and the black fen soils of Cambridgeshire are the chief sources of production. Compared with the consumption of celery in America and on the Continent, the British is low, but it is evident that there is ample room for development, provided methods of marketing and distribution are adopted. Moreover, scientific work on a number of attendant problems has removed much of the uncertainty which formerly surrounded the growing of this crop. As a crop, the production costs of celery are heavy, being next highest to potatoes, and more than four times those of wheat or roots under similar conditions. Nevertheless, it must be emphasized that celery is a crop which pays best when the production costs are not stinted, and that, other things being equal, poor returns are generally associated with low expenditure. If the crop cannot be treated liberally, its cultivation should not be attempted.

The average production costs of good celery will fall between £40 and £45 per acre, but this figure does not allow for the residual value of the manures applied. Although the crop may be grown at a lower production cost figure, a reduction does not necessarily coincide with an economy.

Varieties grown fall into two groups: the whites and the pinks. As celery sells well from the middle of September to the end of January,

MARKET GARDENING (*Continued*)—

large growers usually select varieties which will ensure a sequence of cropping. White varieties are usually preferred, but are less hardy than the pinks; they are, therefore, most suitable for the early and mid-season crops. Good white varieties are **Sandringham, White Gem,** and **Solid White,** the two first-named being the earliest. The best of the pink varieties are **Clayworth Pink, A 1,** and **Leicester Red.** There are also local varieties of considerable merit, and many growers possess their own particular strains.

Soils and Situation—Both soil and climatic conditions enter into successful celery production. Not only must the soil be deep, friable, and easily worked, but it should contain a high proportion of organic matter accompanied also by a high water table. Hence the deep, fine soils of the silts, fens, and warps are highly suitable, the underlying water providing the cool and moist rooting conditions most agreeable to the crop. Climate affects the crop in so far as showery weather in early summer after planting is essential, and bright cool days in late summer and autumn affect the quality of the crop. The crop cannot stand drought conditions, and if once dried out, its ultimate chances of success are poor. Where celery must take its place in rotational farming, it is important to see that the land is given a good rest from the crop, and it should not immediately be followed by cereals. Potatoes or roots are best as followers, and then a cereal, and in this way an economy in manuring is secured in the rotational management of the land.

Manuring—Except on the very best fen land, heavy applications of rotted farmyard or pigsty manure are required. An average soil needs 25 tons per acre, plus from 4 to 6 cwts. of superphosphate strewn down the rows at planting time. The soil need not necessarily be free from acidity. If celery follows cereals or "seeds," the land must be deeply ploughed the previous autumn, otherwise, if following potatoes or roots, an ordinary spring ploughing will suffice.

The plants are raised from seed sown from the end of January to the middle of February in cold frames on gentle hot beds, but the later sowings may be made without the hot beds. About 21,000 plants are required per acre, and it is reckoned that from ½ to 1 oz. of seed should secure this number. Soil sterilization for the seed beds is worth adopting.

It has been established that nearly all celery seed is infected with the spores of Blight (*Septoria apii*), and before sowing the seed should be dressed with formalin solution to destroy these spores. It is emphasized, however, that seed dressing cannot be relied on as a sole means of blight prevention, and spraying must be regarded as the chief means of controlling the disease (see below). The raising of celery plants demands care and attention to detail, and unless growers are prepared to give them, it is better to purchase plants from one of the reputable plant growers.

Planting under field conditions consists of setting out the plants on the flat or in shallow trenches in rows 5 ft. apart, and 4 or 5 ins.

MARKET GARDENING (*Continued*)—

between the plants. Celery planting on a large scale is a skilled operation, and requires three persons to perform it efficiently—one to harrow down and mark out the land, one to drop, and one to insert the plants. Unless the weather at planting happens to be showery, the plants must be watered in.

Horse-hoeing, spraying, and earthing up are the routine operations of cultivation. Celery Blight is seasonal in its virulence, so no rules can be laid down for the spraying of the crop with Bordeaux or Burgundy mixture (which see), either of which will efficiently control the disease, but not less than three sprayings should be given. The cost of spraying an acre of celery is about 8s. The spraying must be thoroughly done and in dry weather. If conditions favouring the spread of disease are prevalent, every two or three weeks will not be too often to spray. Knapsack machines are most effective for spraying, but there are horse-drawn machines more suitable for very large acreages. Spraying results in an improvement in the quality of the crop. (See Insecticides and Fungicides.)

Earthing up to bleach the celery commences when the plants are about the height of a man's knee, and is done with digger ploughs in three furrows, the last, the banking furrow, being augmented by hand work to pack the soil completely round the celery heads. Too early earthing up is a mistake, and may precipitate a form of heart rot. Also, and for similar reasons, the soil must be kept out of the plants' hearts.

Marketing—Celery is commonly sent to market in bundles of about twelve heads, but to obtain the best returns from this system the heads should be graded carefully into two qualities, and each bundle should contain exactly twelve heads. An average crop is fifteen hundred bundles per acre. Grading will result in increasing the monetary returns by several pounds per acre after allowing for the extra cost.

Quite recently an attempt to market celery in an improved form has been made. The heads are stripped, washed, graded, and rolled in impervious, transparent wrappers, and sent to market in wood crates holding 24 lbs.—about three dozen heads. The produce is presented to the public much more attractively in this way, and there are indications that reform in celery marketing, as in the case of other produce, will secure public support and bring better returns to the grower.

Diseases: *Leaf Spot or Blight of Celery* (*Septoria apii*)—This disease attacks both seedling and adult celery plants, and is the most serious disease with which celery growers have to contend. The "leaf spot" stage is first recognized on the outer, older leaves, but it may be present on the leaves and leaf stalks at any stage of growth from the cotyledons to the oldest leaves. Under favourable weather conditions the disease spreads rapidly and the entire foliage becomes withered and brown.

Pycnidia (spore cases) of *S. apii* are found on most samples of commercial celery "seed," and it is chiefly in this way that the disease

MARKET GARDENING (*Continued*)—

is disseminated. The spores from these pycnidia attack the cotyledons of the seedlings and later the disease spreads to other leaves and leaf stalks. (See Seed, Transmission of Plant Diseases by.)

Most damage is done when the weather conditions are such that the celery plant can grow only slowly, whilst the fungus can develop rapidly. Such conditions are found during a spell of dry weather when there is insufficient soil moisture for good plant growth, but there are cool, dewy, or misty nights followed by dull days. Under such conditions the overground parts of the plants remain moist for a considerable proportion of the twenty-four hours. The fungus then grows rapidly, and the plant is unable to overcome the attack, since it is unable to produce new leaves.

If the disease appears in field crops, it can be controlled by spraying a number of times with Bordeaux mixture. (See Insecticides and Fungicides.) The best method of prevention, however, is the use of clean seed. It has been shown that the treatment of infected celery seed hitherto recommended is only partially successful in controlling the disease. Success has now been achieved in the production of commercial quantities of celery seed free from infection with *S. apii*, and the production and use of such seed is regarded as the only satisfactory procedure.

REFERENCE.—H. H. Stirrup and J. W. Ewan, "Investigations on Celery Diseases and their Control," *Min. Agric. and Fish. Bull.* 31, 1931.

Root Rot of Celery Seedlings (*Pythium artotrogus*?)—When celery seedlings are raised in "hot" frames, particularly if the soil has been used previously for the same purpose, they are very subject to a serious root rot disease caused by a species of *Pythium*. The rot usually starts at the tips of the roots and travels upwards. The root tips, and sometimes whole secondary rootlets, shrivel and rot, and become reddish-brown in colour. Seedlings with roots affected in this way droop and collapse on the surface of the soil. In some cases, owing to their extraordinary powers of recovery, some of the affected plants put out adventitious roots and survive.

The disease results from the use of infected soil, and can be prevented by disinfecting the soil used in the frames. This can be done cheaply and effectively by watering the soil with a 2 per cent. solution of formalin at the rate of 2 pints to 4 pints per square foot. The frames are then closed for forty-eight hours. At the end of this time the frames are opened and the soil stirred with a sterilized rake, every day for ten to fourteen days. The stirring frees the soil of formalin fumes, and it is most important that this should be done thoroughly. If any formalin remains in the treated soil, the celery seed will probably fail to germinate. Reasonable care should be taken to prevent reinfection of the soil, and the seed should be sown as soon as possible after the soil has been "sweetened."

REFERENCE.—H. H. Stirrup and J. W. Ewan, "Investigations on Celery Diseases and their Control," *Min. Agric. and Fish. Bull.* 31, 1931.

H. H. S.

MARKET GARDENING (*Continued*)—

CHICORY (*Cichorium Intybus*)—Varieties of the chicory plant are grown both for supplies of salad (as such it is mostly in demand in the winter months) and to provide a vegetable. As the latter it is the blanched tuft of succulent leaves which, after the manner of seakale, is boiled whole and eaten.

Chicory is used extensively on the Continent both as a salad and a vegetable. In recent years it has become more popular in Great Britain, and during the winter months may be found in both forms on most of the home markets.

When used as a salad the chicory leaves are allowed to develop, but they must be well blanched. There are many methods of growing salad chicory for winter use, but in market practice it is advisable to grow the roots in the open ground in the ordinary way and lift and transfer them to darkened frames or pits, which are provided with heat derived from hot-water pipes or hot beds. A moist temperature of about 55° F. will secure a good growth of young leaves. This salad is the *barbe de capucin* of the French. The ordinary common or coffee chicory may be used for the production of the salad.

The use of chicory as a vegetable did not become universal or attract so much favour until the introduction of the **Witloof** or **Brussels** chicory, and this is the variety now generally used. This variety provides extremely tender and succulent heads of excellent flavour and colour, and from Christmas onwards large quantities are sent to England from the Continent. This chicory is forced after the manner of seakale, and the roots for this purpose are obtained by sowing the seed in open land (choosing light, fairly rich soil) during May or early in June. A forcing temperature of about 60° F. will secure the best form of growth, and the heads should be cut before the leaves commence to unfold.

This vegetable ranks as a delicacy and is usually sold by the pound weight.

ENDIVE (*Cichorium Endivia*)—The endives consist of a group of hardy annual plants, supposed to be natives of the East Indies, much grown in all temperate countries for salads. They are much appreciated on the Continent, although large quantities of forced endive are received in British markets from French, Belgian and Dutch growers during the winter months when salads are generally scarce.

There are two distinct groups of endive, consisting of the **Curled** types and the **Batavian** or **Broad-leafed** types. There are many varieties in each group, and, as in the case of the lettuces, names are more numerous than distinct varieties.

Batavian Green, Green Curled, Louviers and **Paris Market** are all good market varieties forming good hearts.

As in the case of lettuces, good crops of endives of high quality can be grown only by making use of rich, light soils with a dry subsoil. Any conditions which impede rapid growth should be avoided, for if checked the plants run quickly to seed. For this reason the

MARKET GARDENING (*Continued*)—

cultivation of endive out of doors during the early summer months should be avoided, unless the crop can be protected and be supplied freely with water. With the approach of cooler days and dewy nights endive may be sown more freely, commencing about the last week of June, employing one of the curled varieties and sowing the seed in what will be a permanent position. The broad-leafed varieties are better for late crops. By sowing at intervals until about mid-August a succession of crops may be obtained, the last sowing providing plants which if given protection will provide a winter supply. Unlike lettuces, the endives make loose hearts only, and are not capable of self-blanching. As unblanched plants are of little value for salad, the plants must be blanched either by tying up or covering with boards, mats, or tiles when nearly fully grown. The last crops in the open ground may be lifted and taken into sheds or greenhouses for protection.

In France, forced endive is produced in large quantities, but the process involves much attention to detail and is hardly suited to the market gardening practice of Great Britain. At the same time a large quantity of this Continental forced endive finds its way on to home markets during January and February.

HORSERADISH (*Cochlearia Armoracia*)—There is a limited but steady sale for the roots of this plant, the uses of which are well known, and it is much grown in the neighbourhood of London, where the largest demand exists. It will grow freely in any soil, but the largest and most saleable roots are produced in a rich, deep, sandy loam which is on the moist side, and from this type of soil also the roots are more easily removed. When well grown, with the resultant roots thick and straight, the horseradish crop may be very profitable, but care and attention to details are essential. Such crops cannot be grown unless the land is thoroughly prepared by trenching it about 2 ft. deep, and by working a good layer of decayed cow manure into the lower 12 ins. The crop is best grown in beds about 6 ft. wide with a narrow pathway between. The crop is propagated from pieces of the main roots saved from the previous crop, about 3 or 4 ins. in length, which are planted in rows 1 ft. apart and 6 ins. deep.

The production of good, straight roots fit for sale depends on the preparation of the sets, and on the treatment of the growths which arise from them. The object should be to obtain and retain only one good growth to each set after the manner of seakale. By paring off the crown end of the set, the number of buds which will form may be reduced.

The new plantations are usually planted up in March, and with a good season's growth saleable roots may be ready by the following autumn, but, as a rule, it may be more profitable to allow two years' growth before lifting the roots. To maintain a regular supply some fresh replanting should be done each year.

Horseradish should be sent to market in a clean condition, made up in bundles of twelve roots.

MARKET GARDENING (*Continued*)—

INDIAN SUGAR-CORN: Syn. **Sweet Maize** (*Zea mays*)—This vegetable, so popular in the United States and Canada, was ignored by Europeans for many years, but is now beginning to be more favourably regarded as a new vegetable. The climate of Great Britain and of other European countries is quite suitable for its cultivation, and market gardeners have already proved that it can be a profitable crop. The seed should be sown in the open ground at the beginning of May in rows 2½ ft. apart, and the plants thinned to 18 ins. apart.

The following varieties are especially suitable for the climate of Great Britain: **Early Premo, Early Sweet Minnesota, Early Kendall's Giant, Early Malcolm,** and **Early Sweet Cory.**

KOHL RABI (*Brassica oleracea Caulo-rapa*)—Although cultivated to a considerable extent on the Continent for the purpose, the kohl rabi has not made very much headway as a crop for human consumption in Great Britain. It is, however, more popular in the towns of the Midlands and the North than in London.

Sometimes known as the turnip-rooted cabbage, the kohl rabi produces swollen, bulb-shaped stems which are consumed when about the size of garden turnips. It resists drought conditions better than the turnip, and is seldom affected by insect or disease attack, but, on the whole, it is inferior to that vegetable. It is, however, a very satisfactory substitute where turnips are difficult to cultivate.

The varieties usually grown are **Early White Vienna** and **Early Purple Vienna,** which resemble each other in everything except colour.

The crop may be treated as any member of the cabbage group by sowing the seed in April, May, and June, in seed beds, and transplanting the plants in rows 18 ins. apart, with 9 ins. from plant to plant, or by drilling the seed thinly where the crop is to stand and singling out the plants. Frequent cultivation to conserve moisture will ensure the production of tender, succulent heads.

The crop resists severe frost very successfully, and in this respect has an additional advantage over the turnip.

LEEK (*Allium Porrum*)—The leek is a market garden crop of considerable importance, as it is a very popular vegetable, particularly in the northern towns of Great Britain. The crop works into a market garden rotation very well, as it can go on to the land following the clearing of the spring cabbage or early pea crop from the end of May until mid-June.

The leek resembles the onion in preferring a light, loamy soil, which has been enriched by the liberal manurial treatment accorded the previous crop. It is an important point to refrain from applying farmyard or stable manure to the land for the leek crop, but a good dressing of soot, from 10 to 20 cwts. per acre, or 1½ cwts. of sulphate of ammonia or nitrate of soda, will act as a useful stimulant to the young plants.

Varieties—Good varieties for market purposes are **Carentan, Musselburgh, Lyon,** the former being most suitable for early production.

MARKET GARDENING (*Continued*)—

The earliest crops are raised by sowing seed in heat in January, and bringing on the plants in cold or slightly heated frames. The main crops are sown in beds in the open ground during February or March, the plants being set out in the field with dibbers when about 6 ins. high. As a rule, the plants are trimmed before planting by having both roots and leaves shortened, and the spacing generally given is from 6 to 9 ins. between the plants, with from 15 to 18 ins. between the rows. A light, smooth roller should be sent over the land when planting is completed, to consolidate the soil round the roots.

In some districts leeks are cultivated like onions, *i.e.*, the seed is drilled in very thinly during Feburary or March, and the crop left to mature on the same land. When this is practised, alternate rows of the crop are lifted for marketing first.

Marketing—Leeks are usually marketed in flat bundles, containing twelve leeks when they are small at the beginning of the season, and six leeks when they are larger in size. They may be either washed or unwashed, but washing improves the appearance and enhances their selling value.

LETTUCE (*Lactuca sativa*)—The lettuce is undoubtedly the most popular of the salad crops. It is in use throughout the year, but particularly during the early summer months, when the demand is very often greater than the supply. Although large quantities of early lettuce are grown under glass, or in frames, the greater proportion of the crops marketed is produced in the open under field conditions. The lettuce is an accommodating plant, and under normal conditions is of rapid growth. It is therefore very suitable as a catch crop for intercropping. The system of intensive cultivation known as " French gardening," much practised on the Continent, for the production of lettuce, has not found general favour in Great Britain as the basis of commercial ventures, although vast quantities of lettuces are imported from France, Belgium, and Holland every year, most of which are grown under this system.

Varieties—There are two distinct types of lettuce, known as the **Cos** type and the **Cabbage** type. The former is an erect plant with straight leaves, and the latter is a flat, rather prostrate plant with crinkled leaves.

There are two distinct crops of lettuce—viz., the **Early** and the **Summer** crops. In many instances the **Early** crop is grown from varieties of a hardier nature than those of the **Summer** crop, as the plants are called upon to survive the winter without protection. The following have established reputation as reliable varieties for market, but it should be pointed out that some of the lettuce-growing districts possess special varieties not found in seedsmen's catalogues.

For early crops (for sowing in the autumn)—*Cos Type:* **Hick's Hardy White, Black Seeded Bath, Winter Green, Paris Green.** *Cabbage Type:* **All-the-Year-Round, Hammersmith Hardy Green, Stanstead Park, Continuity, Tom Thumb,** and **Golden Ball.**

MARKET GARDENING (*Continued*)—

For summer crops (for sowing from March onwards)—*Cos Type:* **Mammoth White, Superb White, Covent Garden White, Paris White.** *Cabbage Type:* **Ideal, Feltham, Malta,** and **All-the-Year-Round.**

Although the cabbage type sells well in the early part of the year, the Cos type is the more generally favoured lettuce, and is consistently the better seller during the midsummer months.

Nearly all the Cos varieties quoted are of the self-folding form, but the grower should always tie Cos lettuces whether self-folding or otherwise, for tying protects the hearts from damage, and the markets' preference is in favour of this method of preparation.

General Cultivation—The lettuce thrives best in an open, porous, yet rich soil. A rich soil ensures rapid growth and tender, succulent produce, and in a salad crop it is always the edible quality which is most important. A soil enriched through the heavy manurial treatment of a previous crop is preferable, but the application of fertilizers in the form of superphosphate and sulphate of potash before planting will promote both texture and quality in the crop. Another important point too often ignored by lettuce growers is the fact that the lettuce requires ample supplies of lime in the soil, and any marked deficiency in this respect will be reflected in the growth of the crop.

Reference was made above to the two broadly distinct lettuce crops. The bulk of the Early crop is obtained by sowing seed of hardy varieties in the autumn (late August or early September). In mild districts the seed may be sown in the open ground, but in more rigorous climates it is safer to sow in cold frames.

In the former case, also, the plants may be put out as soon as ready, but in the latter case it is better to winter them in the seed frames and plant out in the spring. A good distance for planting lettuce is about 9 ins. apart, with 15 or 18 ins. between the rows. Where the grower possesses heated glasshouses, early lettuce may be obtained on a smaller scale by sowing the seed of a quick-growing variety, such as **All-the-Year-Round,** in heat in January. The seedlings are first pricked out into boxes, and later on, after hardening, are planted out in the open to mature. Where lettuce is grown entirely under glass, rich soil and a cool temperature are vital factors. High temperatures will force the lettuce and prevent them from hearting properly.

The summer crops of lettuce are obtained by sowing in succession batches of seed from the middle of March onwards. The first few batches of plants may be transplanted from a seed bed, but as the season advances it is generally safer to drill the seed thinly where the crop is to mature, singling out the plants to 6 or 9 ins. apart. At all times the lettuce grower has to endeavour to provide those conditions which make for rapidity of growth. Good rich soil, appropriate fertilizers, and plenty of surface cultivation to conserve soil moisture will usually provide these conditions.

Marketing—Lettuces should be marketed in a clean and attractive manner. Cos lettuces are usually pulled and sent to market with the roots attached, but the Cabbage types are usually cut. It pays to

MARKET GARDENING (*Continued*)—

make a uniform grade and reject "blown" or "bolted" specimens. The marketing unit is generally one dozen, and the lettuces are packed in hampers or light wooden crates.

Disease: *Ring Spot of Lettuce* (*Marssonia panattoniana*)—When occurring on an epidemic scale, this disease is serious both under glass and in the open. It has occurred on the Continent and in the United States for some years, but has only recently become a serious disease in the British Isles.

The leaf blades and leaf stalks are the parts of the plant affected. The diseased areas on the leaf first appear as brown, water-soaked spots, which usually soon become white with the spores of the fungus. Later, the central dead portions of the spots drop out, leaving holes, with white margins. When infection occurs on the midrib of the lettuce leaf, the spots become elongated, sunken brown patches. The name "rust" is often used by the grower to designate this form of injury. The disease usually starts on the outer leaves, but rain falling on the leaves washes the spores down towards the crown of the plant and the younger leaves become infected. Should the disease spread to the "heart," the whole plant may die.

As the disease is usually perpetuated from the remains of a preceding diseased crop, a system of rotation should be adopted to eliminate this danger. At the same time, manure containing lettuce refuse should not be used. Since one plant with the disease can become a centre of infection which may involve the whole bed, it is desirable to inspect the beds regularly and remove and burn any diseased plants. Under glass, watering should be carried out in such a manner as to prevent water splashing from plant to plant or from leaf to leaf.

REFERENCES.—E. S. Salmon and H. Wormald, "The 'Ring-spot' and 'Rust' Disease of Lettuce," *J. Min. Agric. and Fish.*, vol. xxx., No. 2, May, 1923; E. W. Brandes, "Anthracnose of Lettuce caused by *Marssonia panattoniana*," *J. Agric. Res.*, xiii., No. 5, 1918.

H. H. S.

MINT (*Mentha viridis*)—The leafy shoots of this mint, known as spearmint, are employed for sauces, flavouring, and other purposes throughout the year, consequently there is always a good demand for the crop, which is grown in considerable quantities in Kent, Surrey, Middlesex, and in the vicinity of the large towns of the north of England. This mint prefers a cool, moist soil, and will not yield good cuttings in dry, hot situations.

Propagation of the mint crop is effected simply by dividing the fleshy root stocks in February or March, or by setting out suckers drawn from specially prepared nursery beds during April or May.

The mint is most satisfactory when grown in beds about 6 ft. wide, with alley-ways between. After each season's growth is finished, the beds should be covered with 2 ins. of soil taken from the alley-ways, in order to bury the creeping root stocks which lie on the surface of the ground.

There is usually a keen demand for forced mint, and in many districts

MARKET GARDENING (*Continued*)—

in Great Britain, growers who possess glass houses which may be heated to the appropriate temperature make a speciality of this trade. Mint roots for very early forcing are lifted from the open ground, and are plunged in soil in beds beneath which the hot-water pipes run. Later crops of forced mint are obtained by plunging the roots in soil on the floors of the glass houses.

The forcing of mint may commence in November and continue until March. The temperature of the mint forcing house should be maintained between 55° and 65° F. when the sun is off it.

Disease: *Mint Rust* (*Puccinia menthæ*) — This disease occurs wherever mint is cultivated; it is also found on peppermint and wild species of mint.

The disease is usually first noticed on the plants in spring or early summer. It causes the young shoots and leaves to become abnormally thickened and distorted, and the plants are thus rendered more or less useless. The affected parts become yellow owing to the appearance of the "cluster cup" spore stage. These yellow spores are distributed by wind, rain, and other agencies to the parts of other plants and infect them. Later, pustules of snuff-coloured spores (uredospores) arise and spread the epidemic further during the summer. A third type of spore (teleutospore), which is almost black in colour, is produced in the autumn, and germinates in a mild winter or in the following spring. This type of spore serves to cause fresh infection on the young mint shoots when they arise from the underground stems in spring.

Formerly it was supposed that the mycelium of this rust fungus lived permanently in the underground stems of the mint plant. It is now known that this is not the case, and that reinfection occurs each year from spores.

Mint Rust can be eliminated from established beds by burning off the mint tops not later than the end of September or early October before the resting spores fall to the ground with the leaves. On established beds it is well to repeat this procedure every autumn. The disease can be evaded by establishing, from year to year, fresh mint beds from healthy underground stems. H. H. S.

ONIONS (*Allium cepa*)—The production of onions for market in Great Britain appears never to have overtaken the demand. This is partly accounted for by the fact that the area of soil especially suitable for the crop is not extensive, and partly owing to the high average cost of production of the crop to which available figures testify. A country such as England, with a very large population, must therefore depend very largely on imported onions, and in 1926 the imports of this vegetable reached 18,250 tons, of which over half came from Spain, and the rest mainly from Holland, France, and Egypt. As a comparison the area of ripe bulb onions grown in England and Wales in 1925 was estimated at just over 1,500 acres, giving a total production of 8,300 tons. In the same year, in addition, it was estimated that a further 8,800 tons of green or "spring" onions were grown for

MARKET GARDENING (*Continued*)—

salad purposes. It is evident, therefore, from this statement that the cultivation of home-grown onions may be safely extended wherever suitable soil and climatic conditions are to be found.

Varieties—The bulb onions grown commercially fall into two distinct groups of types—the Spring Sown group and the Autumn Sown, or Tripoli, group. Included in the latter group are the varieties commonly grown for pulling in the spring as green, or salad, onions. Pickling onions are obtained by sowing in April on poor soil the smaller varieties of the Tripoli group. The best varieties for market purposes are: **Bedfordshire Champion, Up-to-Date, Giant Zittau, White Spanish,** and **Rousham Park Hero** of the spring sown group, and **Giant Rocca, White Tripoli,** of the autumn sown group. **White Lisbon** is the best variety for pulling in the green state, and **Silver Skinned** and **Queen Pickling** are the best for the pickling trade.

Cultivation—Successful onion culture depends considerably on the nature of the soil on which the crop is grown. The ideal soil is a deep sandy, or medium loam, which must be well drained, and as onions are gross feeders, the soil should also be rich. Various methods of enriching soil for onions are practised by commercial growers. In some districts as much as forty loads per acre of farmyard or stable manure are used, while in others half this amount, supplemented with fertilizers, is given. In the Biggleswade district of Bedford, where about a quarter of the English onion crop is grown annually, 100 bushels of soot to the acre is considered to be a sufficiently good manurial treatment for onions, provided they follow a crop previously well dressed with dung. In any case, onions demand copious supplies of phosphates, nitrogen, and potash, and good crops cannot be grown in soils deficient in these plant foods. It was once the practice to fallow land which was intended for onions, but this is not now always convenient. The land should, however, have a good preparation by ploughing in October or November, followed by thorough cultivation and rolling in the early spring to provide a firm, tilthy seed-bed by the middle of February. From that date until the middle of March the seed may be drilled on the first favourable opportunity.

Although large quantities of onion seed come from California, English or European seed has been found to give the heaviest crops owing to the earlier ripening off of the crops grown from the first-named. Onion seed loses its vitality very quickly, and only tested seed should be sown. There are many strains or stocks of the varieties given above, and only by securing reliable seed can growers avoid the risk of disappointment in their crops. For bulb production the seeding rate should be from 6 to 10 lbs. per acre, but for green salad onions from 20 to 28 lbs. per acre can be put in.

Harvesting and Marketing—Onions should be pulled when the roots begin to wither and the bulb parts readily from the soil. A careful and thorough drying of the crop is very essential if it is to be stored successfully. During showery weather the bulbs must be constantly moved to prevent second growth. When thoroughly dry the crop

MARKET GARDENING (*Continued*)—

may be stored in onion stores (dry barns or sheds), usually on tiers of specially made drying shelves through which air can freely circulate. Dampness will tend to start the onions into growth, besides promoting destructive diseases such as Grey Mould (*Botrytis Altii*), so dry conditions and plenty of ventilation should always be maintained in an onion store until the whole of the crop has been marketed. English onions are usually marketed in 1 cwt. bags.

Diseases: *Downy Mildew of Onions* (*Peronospora Schleideni*)—As happens with other Downy Mildews, the amount of damage done by this disease to the onion crop is greatest in wet seasons. Under such conditions very serious losses are often experienced.

In the earlier stages, the disease either appears as a general yellowing of the foliage or exhibits itself in the form of pale spots or blotches on the leaves. Under moist conditions the affected leaves bear a delicate purplish bloom of conidiophores. The spores thus produced are distributed to neighbouring plants, and under wet weather conditions epidemics of the disease are thus brought about.

The Mildew does not confine itself to the leaves, but grows down into the bulbs, where it may persist over the winter. Onions containing perennial mycelium, if used for seed purposes, produce spores on the new leaves and may be the means of starting an epidemic. Bulbs for seed, therefore, should be saved only from healthy crops.

Resting spores are also formed within the dead tissues of the host and may be liberated into the soil. They constitute another source from which a crop of onions may become infected. It follows, therefore, that onions should not be sown in soil that has previously carried a diseased crop.

Direct combat of the Mildew, by spraying or dusting, has been advocated from time to time; but the results have not always been successful. Some varieties of onions are generally prone to attack by Downy Mildew, whilst others appear to be more resistant. Where onions are grown from "sets," it has been found that heating the onion "sets" which contain the hibernating mycelium to a temperature of 104° F. (40° C.), for a period of not less than eight hours, kills the fungus without seriously injuring the bulbs for planting purposes. This promising method of control requires further testing before it can be generally recommended.

REFERENCES.—P. A. Murphy, "The Presence of Perennial Mycelium in *Peronospora Schleideni*," *Nature*, vol. cviii., p. 304, 1921; P. A. Murphy and R. McKay, "The Downy Mildew of Onions (*Peronospora Schleideni*), with Particular Reference to the Hibernation of the Parasite," *Sci. Proc., Roy. Dublin Soc.*, vol. xviii. (N.S.), No. 22, July 30, 1926.

Neck Rot of Onions (*Botrytis alii*)—This is often a troublesome storage disease of onions. Infection generally occurs in the field during or following harvesting of the bulbs. The fungus usually enters at the neck of the bulb, and later, under storage conditions, gradually passes down into the bulb between the three or four outer

MARKET GARDENING (*Continued*)—

scales. If such bulbs are stored under humid conditions, the fungus causes a soft, brownish rot of the scales. The affected tissues become covered with the greyish mycelium and spores of the fungus, and later small black sclerotia are also formed. Sometimes the base of the bulb is first attacked by infection from the soil.

White varieties are more susceptible to attack than coloured ones, and onions which are soft and poorly matured are most liable to the disease, as they dry with difficulty. Late applications of fertilizers which tend to delay maturity should be avoided. Onions with thick necks are also very liable to the disease.

Onions should be properly dried before storage. The places in which they are to be stored should be kept dry and well ventilated. It has been found that artificial curing of the bulbs after harvesting, so as to desiccate the neck tissue within a fortnight, greatly reduces losses in storage.

References.—J. C. Walker, "Control of Mycelial Neck Rot of Onion by Artificial Curing," *J. Agric. Res.*, vol. xxx., p. 365, 1925.

Onion Smut (*Urocystis cepulæ*)—This disease attacks leeks and shallots as well as onions. It is an important disease in parts of the United States, but fortunately has not yet become common in England. Because of its serious nature, the disease is scheduled by the Ministry of Agriculture under the Destructive Insects and Pests Act, and is notifiable to the Ministry.

Infection occurs only when the plant is quite young, from spores in the soil. The first sign of attack is visible in the form of dark, opaque spots or streaks beneath the skin of the first and succeeding leaves. Attacked leaves are often abnormally thickened, and twist and bend downwards. Later, the skin over the dark areas splits, and powdery black masses of spore balls are exposed. Some of the spore balls pass into the soil, which may remain contaminated for several years.

It has been found that where the soil temperature is 29° C. or higher, infection cannot take place. High temperatures following sowing, therefore, are favourable to the production of healthy seedlings. Since infection of the young plant from the soil can take place only through the first young leaf, there are definite limits to the susceptible period. Under normal conditions it lasts for about two or three weeks from the time of sowing. Transplanted onions can be grown in contaminated soil, as the plants cannot be infected after the seedling stage.

It is possible to ward off smut attack sufficiently to enable reasonable stands of healthy onion seedlings to be obtained in contaminated soil. This is done by applying a weak solution of formalin (1 in 120 parts of water) to the drills at the time of sowing. This treatment by no means exterminates the smut fungus from the soil, and it must be repeated with each successive sowing.

References.—A. D. Cotton, "Onion Smut: A Disease New to Britain," *J. Bd. of Agric.*, xxvi., pp. 168-174, 1919; J. L. Walker and L. R. Jones, "Relation of Soil Temperature and other Factors to Onion Smut Infection," *J. Agric. Res.*, vol. xxii., p. 235, 1921.

MARKET GARDENING (*Continued*)—

White Rot of Onions (*Sclerotinia cepivorum*) may cause considerable damage to onion crops, especially in market gardens and allotments. In some parts of the country it is called "mouldy nose"; in others it is often, though erroneously, termed "mildew."

The effect of white rot, as seen on the foliage, somewhat resembles an attack of the maggot of the onion fly. That disease, however, is distinguished by the presence of the maggots in the bulbs and the absence of the white fungus.

Onions become attacked when the soil on which they are sown or planted is contaminated with the fungus. The first signs noticed are a wilting and yellowing of the foliage. If such plants are pulled up gently, they come away easily. The roots have usually been destroyed and the fungus has spread to the bulb. This white fluffy mycelium round the bulb is characteristic of the disease. Later, numerous small black bodies (sclerotia or resting masses of mycelium) appear. By means of these the parasite persists in the soil from year to year. Finally the bulb becomes shrunken and dried up.

White rot is a soil-borne disease and not introduced with the seed. When once it becomes established in any part of a field or garden, it is only by starving out the fungus from the soil that it may be exterminated. This means that the ground should be kept free from onions for a number of years. When once the bulbs become attacked, nothing can save them. Diseased plants should be removed and destroyed as soon as possible. No success has been obtained with soil fungicides, as the hard coat of the sclerotium is very resistant to chemicals. No varieties are immune, but shallots are usually resistant, and leeks not commonly affected.

REFERENCE.—A. D. Cotton and M. N. Owen, "The White Rot Disease of Onion Bulbs," *J. Bd. of Agric.*, vol. xxvi., p. 1093, 1920.

H. H. S.

PARSLEY (*Carum petroselinum*)—Parsley is grown in considerable quantities as a field crop in most of the market gardening districts of Great Britain, the Biggleswade area of Bedfordshire being the most important one, as its light, sandy soil is particularly suitable for parsley cultivation. The demand for parsley is fairly constant throughout the year. The bulk of the parsley crop consists of the varieties which are grown for the sake of the leaves, the foliage parsleys, which are employed for various culinary purposes, such as flavouring, sauces, and garnishing. There is also a demand, chiefly from the Jewish community, for the **Turnip-rooted** or **Hamburg** parsley, the roots of which are consumed as in the case of parsnips, and for the **Celery-leaved** or **Neapolitan** parsley, the leaf stalks of which are consumed, when blanched, as in the case of celery.

Varieties—There are three distinct types of the parsley grown for its foliage, which are known as **Common** or **Plain Parsley,** with plain unattractive leaves; **Fern-leaved Parsley,** with very ornamental fern-like leaves; and **Curled Parsley,** with frilled, finely curled and highly

MARKET GARDENING (*Continued*)—

flavoured leaves. The **Common Parsley** is the most prolific in growth, but its flavour is inferior to the other types. The **Fern-leaved,** a very ornamental variety, is the most effective type for garnishing purposes. The bulk of the foliage parsley trade is done with the **Curled** type, of which there are many varieties giving a wide range of curliness and also bushiness of growth habit.

Good light loams will suit the parsleys best, and for the **Hamburg** type a good depth of soil is very important.

The seed of all types of parsley may be sown in March, but two or three sowings spread over several weeks should be made of the foliage parsleys to provide a succession. These parsleys should also be sown again in July to provide the winter and spring crops. The plants will stand a normal winter quite successfully, and, as a rule, the late sown crops are the most profitable.

The seed should be sown in drills 1 ft. apart, and the plants are thinned to from 6 to 10 ins. apart. The **Hamburg** type may be given from 10 ins. to 1 ft.

The **Neapolitan** should be treated like celery, transplanting the young plants to prepared trenches or open land where provision for earthing up can be made. This plant thrives under less moist conditions than those required by the true celery, a factor which might be more generally taken advantage of in districts where the latter crop does not thrive well.

PARSNIP (*Pastinaca sativum*)—The cultivated parsnip is one of the most nutritious of the root crops grown for human consumption, and in food value approaches more closely to that of the potato than any other of the vegetables. (See Feeding Stuffs.) It deserves to be more freely consumed on this account, but it must be admitted that the present rate of production seldom seriously exceeds the demand.

Varieties—There are several varieties of parsnips, but only **The Student** and the **Hollow Crown** varieties are grown extensively for market. **Lisbonnais** is an improved form of the **Hollow Crown** variety.

Cultivation follows the lines laid down for other root crops. Owing to the fact that the roots must be lifted with hand-forks, a light but rich sandy loam is the best for the parsnip crop. Both the size and the edible quality of the roots may be considerably improved with the aid of fertilizers, especially those supplying phosphates. When preparing the land for the seed, therefore, it is advisable to apply 5 cwts. of superphosphate or 7 cwts. of basic slag to the acre, and a dressing of sulphate of ammonia (1 cwt. to the acre) both just before the seed is drilled and again after the plants are singled will also be very beneficial. Parsnip seed is usually sown from the middle of February to the middle of March, and where crops tend to develop "canker" or "rust" (a non-parasitic trouble) the later sowings are often found to give the best results. From 6 to 8 lbs. of seed per acre are generally used. The parsnip is a lime-loving plant, and ap-

MARKET GARDENING (*Continued*)—

plications of lime, especially on rich soils, are very helpful. Agricultural salt, from 5 to 10 cwts. per acre, also assists in keeping down "canker" on some types of soil.

Parsnip seed is very light, and as it is difficult to drill alone it is sometimes mixed with sand or a little grain to provide a "carrier."

The seed does not retain its vitality very long, and therefore only tested seed should be sown.

Marketing—A good crop of parsnips may run up to 12 tons per acre. The roots should be carefully lifted, as required, from the end of September onwards. Frost will not harm the crop, so it may remain on the land as long as convenient. The roots are sent to market in boxes or baskets, and it is not necessary to wash them.

PEAS, GREEN OR GARDEN, EDIBLE PODDED, AND CANNING (*Pisum sativum*)—The acreage devoted to the cultivation of green peas is probably the largest in extent next to potatoes. In 1929 the area of the crop was returned at 53,860 acres, which did not include the crop grown for canning. Kent, Middlesex, and Essex are the chief producing countries, other important areas being Worcestershire, Cambridgeshire, and parts of Lincolnshire.

The art of green pea growing is the maintenance of a sequence of supply, and with the range of varieties now available it is possible to gather crops from the end of May until the end of September. The late pea crop, although rather speculative owing to its dependence on the weather and on the effect of mildew, is often very profitable, and pea growers have found it worth their while always to make provision for it in their cropping programme.

Varieties—Green peas is one of the crops which have given considerable trouble in the matter of the preservation of variety type, owing to the very pronounced innate habit of producing variants or rogues even when full precautions are taken against cross-fertilization. The late Professor Bateson and his colleagues of the John Innes Horticultural Institute studied this inherent tendency of the pea to exhibit variation, and their work has shown the importance that thorough roguing plays in keeping stocks true to type. Unless the seed crops are carefully rogued each year, there is a danger of the variety type character being considerably obscured, or, indeed, completely lost. There are three main groups of green peas: Early Varieties, Second Early Varieties, and Main Crop and Late Varieties; amongst seed growers, however, peas are usually classified into two groups: Round Seeded Varieties and Wrinkled Seeded Varieties. Good profitable varieties suitable for most districts are: Early Varieties—**Eclipse, Early Bird, Peter Pan, Meteor, Benefactor,** and **Laxton's Superb.** Second Early Varieties—**Pioneer, British Lion, Lincoln, Thomas Laxton, Bedford Champion, Union Jack,** and **Little Marvel.** Main Crop and Late Varieties—**Admiral Beatty, Telegraph, Alderman, Autocrat,** and **Chancelot.**

Cultivation—Green peas will succeed on a variety of soils, but for market the crop is safest on deep, good-textured loams where moisture

MARKET GARDENING (*Continued*)—

is not quickly lost. Cold clay soils will retard the maturing of the crop, and a certain amount of lime in the soil is a necessity. Heavy applications of farmyard manure are not suitable for peas, the crop doing much better on land which was well manured for a previous crop, such as potatoes or one of the cabbage family. The crop does, however, respond well to certain fertilizers, especially those supplying phosphates. Just before sowing, therefore, from 4 to 6 cwts. of superphosphate should be worked in, and if potash is notably deficient, from 1 to 1½ cwts. of sulphate of potash should accompany it. Nitrogenous manures, unless carefully used, promote rank, unfruitful growth, and reduce the yield of peas.

The earliest crops of peas are usually taken from those sown the previous autumn to stand the winter. The variety **Eclipse** and other round-seeded varieties should be sown thickly (3½ bushels to the acre) in November, for this purpose. The spring sowings (again commencing with the round-seed varieties) should commence during February where the land is in a suitable condition, from 2½ to 3 bushels of seed to the acre. A good distance between the rows should be allowed to permit of cultivation, from 20 to 30 ins. being usual. The average time taken by a crop of peas from seeding to picking is four months. Frequent cultivation between the rows, at first with horse hoes, and later with hand hoes, is very essential to ensure good growth, and to keep down weeds.

Marketing—Women and children usually undertake the work of pea picking, the plants being pulled up and cleared as the work proceeds. The peas are sent to market in light bags holding a stated weight, usually 28 lbs.

Edible Podded, or Sugar Peas, "Gourmand Peas," or "Pois sans parchemin," are a distinct group of peas from those described above—the shelling peas. Edible podded peas are neither grown nor consumed to any extent in the British Isles, but on the Continent they are a very popular vegetable and much grown commercially. As the French descriptive name indicates, the pods of these peas lack the tough, parchment-like inner membrane which characterizes the shelling group, and consist of a simple cellular tissue containing a considerable amount of sugary sap. They are cooked and consumed in a whole condition.

Varieties—There are tall and dwarf varieties of these peas.

Canning Peas, while grown in the field on lines similar to those described above, consist of varieties especially suitable for canning. With the advent of a new market afforded by the recent rapid growth of the canning industry, the cultivation of these peas should extend considerably. These peas are actually in great demand at the present time, and considerably over 1,000 acres are being grown in the Lincolnshire and Cambridgeshire pea-growing districts on a contract basis for the canning factories. Special shelling machines are employed for handling these crops. (See Preservation, Fruit and Vegetables.)

MARKET GARDENING (*Continued*)—

Varieties of peas deemed most suitable for canning are **Petit Pois, Lincoln, Alaska, Admiral,** and **Surprise.**

POTATO—See article Potato.

RADISH (*Raphanus sativus*)—The radish is an important market-garden crop. It is not difficult to grow where soil conditions are suitable, and as it takes only about six weeks to mature, it can be worked conveniently into the cropping plan as a catch crop. Radishes always meet with a ready demand in the spring and early summer months, and in the Evesham district the production of early radishes is made a speciality. There the radish beds are a feature of the landscape from the first week in January onwards, and very large quantities of the vegetable are dispatched to markets all over Great Britain. Elsewhere, early radishes are obtained from seed sown in cold glasshouses or in frames on hot beds, while later in the year radishes are grown in all the market-gardening districts under open-field conditions.

Varieties—There are long, oval, and round forms of the radish. The public, on the whole, prefer the oval or olive form, but the round or turnip shaped form is also very popular during the summer months. The oval form is the most suitable for early production, although Wood's Early Frame, one of the long forms, is still extensively grown where frame cultivation is practised.

Reliable market varieties of radishes are:

Oval Form—**French Breakfast** (of which there are two types, one making very little top and being most suitable for frame and house culture), **Olive-Shaped Scarlet.**

Round Form.—**Sparkler, Scarlet Ball, Turnip-Shaped Red, Turnip-Shaped White-Tip.**

Long Form.—**Wood's Early Frame, Long Scarlet.**

There are several white varieties of radish, but these are not so favourably received on the markets as the coloured or partly coloured varieties.

General Cultivation—The radish requires a rich, deeply worked, friable soil, which should also contain plenty of lime.

The bed system of growing radishes, which is practised in the Evesham district, requires the use of large quantities of straw. If cheap straw is available, the radish beds may be laid up 6 ft. wide with pathways between, and choosing sheltered positions. Commencing in late December, sowings of seed are made at intervals during January and February, covering each area of beds sown with about 6 ins. of straw. During mild weather the straw may be raked off into the alleyways, and after the plants are above ground it should be replaced by a light covering only in the event of spells of frosty nights or cold winds.

On open land the seed may be sown, either broadcast or in drills, from the end of February to September. Later sowings should be in drills 12 ins. apart to permit of cultivation during hot, dry weather. Thin sowing should be the rule always.

Marketing—Radishes are marketed in bunches of twelve, and should be well washed after pulling. A selling unit is usually a dozen, or a score, of bunches tied together in bundles.

MARKET GARDENING (*Continued*)—

RHUBARB (*Rheum Rhaponticum*)—Rhubarb has now become one of the important market gardening crops, and in some districts, such as in the vicinity of Leeds and of Glasgow, the crop has developed to such an extent as to become one of the staple industries of the land. From these areas very large quantities of rhubarb, principally the forced kind, are distributed to all the large cities of the Midlands and the North, and even to London. The supplies to the London market are augmented from the market gardening districts around the city. Although the commercial cultivation of rhubarb has become somewhat localized, there is no really adequate explanation of this fact, as the crop does well on a wide range of soils, and, in fact, the moisture-holding capacity of the soil is its only important requirement. The ideal soil for rhubarb is a deep, rich loam; shallow, dry soils should always be avoided. The plant is also a gross feeder, and requires plenty of organic matter for the production of good crops.

Rhubarb cultivation usually follows two lines of treatment—viz., the production of "natural" or open land crops during spring and summer, and the production of "forced" crops for marketing during the first three months of the year. It is important to note that not all varieties in cultivation are equally suitable for both purposes. Certain varieties do not force well, and another noteworthy point is that the growth and cropping capacities of varieties tend to differ according to the localities.

Varieties—For market purposes the red or pink-coloured varieties are always preferred to the green-stemmed kinds. The chief commercial varieties are **Dawe's Champion, Prince Albert, Victoria, Sutton's Seedless, Linnæus,** and **Hawke's Champion,** and of these the first three respond well to forcing. **Victoria** is a standard market variety of great merit, both for outdoor culture and for forcing.

Cultivation—It will be clear that the rhubarb growers must practise two distinct methods of cultivation, and these will be separately described.

Natural Rhubarb—As rhubarb can remain on the land without being disturbed for from five to eight years from the time of planting, the land should always be thoroughly prepared for the crop. A good application of farmyard manure, up to 40 tons per acre, should be given either at the first or second ploughing, according to the nature of the soil. A first ploughing in the autumn, and a second, a cross-ploughing, in the spring, followed by a good surface cultivation, should prepare the land for planting, which takes place in February or early March. The planting sets (divided crowns) are usually ploughed in deep enough to give a surface covering of 2 ins., from 30 to 36 ins. apart in the rows with 4 ft. between the rows being suitable distances to plant. Experimental work has shown that applications of fertilizers, especially during the third and subsequent years, are extremely beneficial. During the April following planting an application of 2 cwts. of sulphate of ammonia or nitrate of soda will be very valuable to the young plants, and this nitrogenous dressing should be continued every spring. After the third year a compound dressing, consisting

MARKET GARDENING (*Continued*)—

of 4 cwts. of superphosphate, 2 cwts. of sulphate of potash, and 1 cwt. of sulphate of ammonia should be applied during January.

It is a great mistake to overpull a field of rhubarb during the first two years. During the first year after planting only one, or at the most two, pullings should be taken. In the second year three pullings are permissible, and when the plants are strongly established, as many as five or six pullings may be taken. A covering of long litter in the early spring over the crowns will promote early growth. Lime is an essential factor in securing healthy growth, and should be supplied in small lots of from 4 to 5 cwts. per acre each year.

Forced Rhubarb—The outdoor activities of the rhubarb forcer are centred round the production of a continuous supply of crowns for forcing. In practice it is recognized that for every acre of forcing sheds he possesses, the grower must have approximately 12 acres of crowns ready for forcing. As a rule, the crowns are not forced until they are three years old, although in the Leeds district the Prince Albert variety is forced after two years' growth. For the forcing of 1 acre of three-year-old crowns the grower will therefore require 36 acres of land under rhubarb, and in addition a further 4 or 5 acres to supply stock. In other words, an acre of forcing sheds requires approximately 40 acres of land to maintain it from year to year. The commercial forcing shed should be a span-roofed structure from 25 to 30 ft. wide, on walls 2 ft. high, and rising to 10 ft. in the centre. The sheds should be perfectly dark and heated with hot-water pipes raised a few feet from the floor.

Rhubarb crowns for forcing are usually lifted, after growth has died away, during November and December, and if allowed to be exposed to the action of frost for a period they will respond more freely to forcing than otherwise. Heat and moisture are the chief factors in forcing rhubarb. After the crowns are put in the sheds the temperature should be gradually raised; for the first week not above 45° F., the second week not above 50° F., and then by further stages to 60° F., which should not be exceeded if a firm, good coloured crop is the object. The crowns should be kept moist, but not saturated, and the atmosphere of the shed should be humid at all times.

Marketing—Rhubarb when naturally grown is marketed in various ways, according to the district. In the London area bundles of from 5 to 8 lbs. are used, or the sticks are consigned loose in boxes holding 30 lbs. In other districts larger bundles of 14 and 28 lbs. are used. Forced rhubarb must be carefully packed and is usually put up in bundles of from 6 to 12 ozs. in weight, tied with soft string. It is estimated that an acre of three-year-old crowns will yield from 12 to 13 tons of forced rhubarb.

Disease: *Crown Rot of Rhubarb* (*Bacterium rhaponticum*)—This is a serious bacterial disease. The infecting organism may enter the "crown" at soil level, or may pass upwards through lateral roots to the crown. It produces a soft, brown rot near the "crown" of the root, and also causes the bases of the stalks and sheathing leaves

MARKET GARDENING (*Continued*)—

to become discoloured and swollen. The foliage leaves are puce-coloured, the terminal bud is absent, and only spindly rhubarb sticks are produced from the lateral buds.

When new "sets" are planted in infected soil, the disease may be contracted in the first year, but it does not generally show itself before the second year, and once a plant becomes infected, it is impracticable to cure it. The disease is cumulative owing to the practice of growing rhubarb on the same land for many years. It is spread through the soil by the incorporation of infected tissues. Careful attention to plant hygiene and crop rotation is the best method of reducing the amount of disease.

Efforts have been made to get rid of the disease germs from contaminated soil, and for this purpose a solution of ammonia has been found to be very effective. Refuse heaps, if treated with ammonia, may be used as manure without fear of reinfecting the soil.

No varieties of rhubarb have been found to be immune to the disease, but the variety "Victoria" appears to be more resistant than others.

REFERENCE.—W. F. Millard, "Crown Rot of Rhubarb," *Univ. Leeds and Yorkshire Council for Agric. Educ. Leaflet* 134, 1924.

H. H. S.

SALSIFY (*Tragopogon porrifolius*)—This biennial plant, a native of Great Britain, has long been cultivated for the sake of its white, fleshy roots, in shape resembling carrots, which are consumed as a vegetable chiefly after the manner of parsnips, but also in other ways.

The salsify crop succeeds best in a rich, mellow loam such as will suit other root crops, and no manure should be applied to the land previous to sowing. The general cultivation of the crop also follows the lines laid down for other root vegetables, the seed being sown in drills 1 ft. apart, during April. It is usual to make a second sowing about the middle of May in case the first sowing produces a large proportion of plants which run up to seed, when the roots are useless. The plants should stand about 6 to 8 ins. apart in the rows, and with normal routine cultivation the crop is ready for use from October onwards. The root is almost as hardy as the parsnip, but severe frost may damage it. The variety known as **Mammoth** yields large, white roots of a good shape and texture.

SCORZONERA (*Scorzonera hispanica*)—This plant has a root that is used as a vegetable after the manner of salsify, which it much resembles save that the skin is black. It is a native of Spain, and is really a perennial, although only the roots formed during the first year's growth are regarded as of any value for marketing. The plant is quite hardy, and although the roots may be left in the ground, it is advisable to take up a supply and store it in sand against severe weather. Roots left in the ground may be used up to April or May of the following year, at which time they usually run up to seed. A deep, loamy soil on the light side, and an open situation suit the crop best; the general lines of cultivation are similar to those employed for salsify.

The variety known as **Giant Russian** is the best for market purposes.

MARKET GARDENING (*Continued*)—

SEAKALE (*Crambe maritima*)—Seakale is cultivated extensively as a market garden crop, but, as in the case of rhubarb, the crop has tended to become localized. This fact, however, admits of explanation, since the natural habitat of seakale is the seashore (it still grows wild on many of our coasts), and consequently it thrives best in light, sandy soils.

The commercial cultivation of seakale turns on three aspects. The first and most important is the production of the forced seakale, which appears on the market during January, February, and March, when, owing to the scarcity of other fresh vegetables, it usually meets with a ready sale. The second aspect is the production of open land or "natural" seakale, which follows the forced article. The remaining aspect is the production of forcing crowns for sale to seakale forcers who are not in a position to grow their own. In any case the same conditions as to soil requirements are necessary—viz., a deep, fertile, well-cultivated, sandy loam which should be well drained and liberally supplied with lime.

Varieties—The variety of seakale grown commercially is the **Lily-white,** of which many strains, peculiar to localities and even individual growers, exist. As seakale is propagated vegetatively it is possible to maintain stocks in a very uniform condition and free from mixture of undesirable types.

Propagation—As stated above, seakale is propagated on commercial lines, not by the sowing of seed, for although this is quite feasible it is undesirable, but by the planting of root cuttings known as "thongs." These are portions of the thick lateral roots about 6 ins. long, taken from the fully grown crowns when they are lifted and "dressed" in preparation for forcing. The end of the "thong" nearest the main root is always cut squarely across, and the end farthest away in a sloping direction. When laid in moist sand for fine earth these prepared "thongs" will "strike" (the formation of embryo buds at one end and roots at the other) by planting time, that is during March and April. The "thongs" should be set out on land which has been thoroughly prepared and which was well manured for a previous crop. A good distance for planting is from 10 to 12 ins. apart with 18 or 24 ins between the rows, the top of each "thong" being covered by at least 1½ ins. of soil. Several buds will form on each "thong," but these should be reduced to a single crown during the month of June or July. It may take from one to three years to grow a forcing crown according to the size of the "thong" planted, richness of soil, etc. Frequent cultivation and the application of fertilizers—1 cwt. of nitrate of soda and 2 cwts. of sulphate of potash—will promote rapid and healthy growth. Seakale is also benefited by the application of common salt, 1 cwt. to the acre, and old soot, about 20 bushels to the acre. Also, when preparing the land for planting, from 4 to 6 cwts. of superphosphate should be worked in at the final cultivation.

Forced seakale is produced on lines somewhat similar to those followed for forced rhubarb. The crowns, when large enough, are lifted in November and December, and after being "dressed" and graded are held

MARKET GARDENING (*Continued*)—

in readiness for supplying the forcing pits with a succession of batches. Seakale forcing pits are usually a series of low, dark, sunken structures, heated by hot-water pipes, the latter running beneath the beds of soil in which the crowns are plunged. As in the case of rhubarb, the temperature of the pits must be carefully regulated, and it should not be allowed to go above 60° F. if kale of good, tender quality is desired. It takes about four weeks to force seakale.

Natural seakale is produced by covering the beds in which the crowns were grown with about 6 ins. of fine soil or fine ashes, and cutting the heads as soon as the tips of the growing stalks push through this covering.

Marketing—Seakale is usually marketed in boxes of 8 lbs. net weight, or in the case of the earliest forced kale, in punnets of 2, 3, or 4 lbs.

Seakale growers should guard against a destructive bacterial disease, known as *black rot*, by the maintenance of hygienic methods of cultivation and by keeping the soil freely supplied with lime.

REFERENCE: *Seakale Cultivation*, Sectional vol. No. 12, *Min. Agric. and Fish.*, 1928.

SPINACH (*Spinacia* sp.) — Spinach is consumed in considerable quantities, and constitutes a valuable market garden crop, especially as it can be grown quickly, and can often be taken off the land as a catch crop following early potatoes, peas, etc. Spinach does best in a deep, loamy soil, which should be in a high condition of fertility to ensure the best results.

Actually, there are two distinct varieties of spinach in cultivation. These are the **Smooth-seeded, Broad-leafed, or Summer** spinach (*Spinacia glabra*), and the **Prickly-seeded, or Winter Spinach** (*Spinacia oleracea*). There is also another variety known as **New Zealand** spinach (*Tetragonia expansa*), which forms a plant of very dense growth possessing the merits of being able to withstand hot, dry conditions, and to maintain a supply of edible growth long after the other varieties have come to an end. The **Flanders** spinach and **Lettuce-leafed** spinach are forms of the **Smooth-seeded** spinach suitable for winter crops. **Spinach Beet** (*Beta Cicla*), known also as **Perpetual** spinach, is grown as a substitute for the true spinach during the autumn and winter months, but its quality is inferior. This plant is really a member of the beet family.

The first sowings of summer spinach may be made as soon as the soil is in a fit condition, and from then onwards sowings may be made every few weeks until about the second week of August. The later sowings are somewhat speculative, depending for success on the weather, but extremely profitable crops are often raised from them.

The seed of summer spinach should be drilled thinly in rows 12 ins. apart.

The **Flanders** and **Lettuce-leafed** forms should be sown from about the first week of August until early September to furnish crops for the autumn and winter.

The **Prickly-seeded** spinach should be sown during July and August,

MARKET GARDENING (*Continued*)—

drilling the seed in rows from 15 to 18 ins. apart. **Spinach Beet** should be drilled in rows 18 ins. apart during the same period.

All plants of spinach should be thinned if overcrowded, and the strong growing forms, such as the **Spinach Beet,** should be thinned to at least 6 ins. apart.

Summer spinach is usually gathered by pulling the plants, thus clearing the ground of the crop, but individual leaves are picked in the case of all other forms.

Spinach is usually sent to market in hampers loosely packed, but holding weight units of 40 lbs. Summer spinach is sometimes rinsed in water before despatch to remove grit and soil from the roots, a procedure which also freshens up the produce and raises its selling value.

TURNIP (*Brassica rapa*)—**Garden Varieties**—A large number of varieties of the turnip are grown for human consumption in all the market gardening districts, and are generally classed as "garden" turnips, differing from the "field" turnips in being smaller in size and superior in texture and flavour.

The turnip not infrequently serves a dual purpose as a market garden crop, as the tender leaves and shoots which spring up in the early spring from the crops of roots which have stood the winter may be gathered and sold as "greens." In years of shortage of other forms of green stuff these crops of greens often realize good prices.

Varieties—In addition to the group of "white" turnips, the term by which they are known on the markets, varieties of the **Swede turnip** (*Brassica Napus*) are also grown for human consumption. The **Swede turnip** is a very popular vegetable in the northern towns of England, and as it possesses the merit of being of hardier constitution than the **White turnips**, it is a reliable crop for standing the more rigorous of our climates.

The garden turnips embrace a range of varieties possessing both coloured skins and coloured flesh. The skin colours are all white or all yellow, or white with purple, yellow, red, or green tops, and the flesh colours range from pure white to a rich yellow. As a general rule, only the white, yellow, and green-topped varieties are grown extensively for market.

A group of early varieties is known as "six weeks," and of these **Early White Stone** and **Early White Dutch** are usually satisfactory if of good stock.

For mid-season cultivation **Green Top Stone** and **Golden Ball** usually give satisfaction, and for winter crops **Manchester Market** and **Winter Green Top** may be relied upon.

To ensure the production of attractive, good quality turnips, the crop should be grown on a rich soil which preferably was well manured for the previous crop. Light, sandy loams are the most suitable soils, as heavy, retentive soils do not encourage rapid growth, and there is a tendency for the plants to "bolt" to seed.

The seed should be drilled in from the middle of April onwards for early and mid-season crops. In warm districts earlier sowings may be made, but, as a rule, the later sowings make more rapid growth.

MARKET GARDENING (*Continued*)—

The drills should be from 15 to 18 ins. apart, and from 2 to 4 lbs. of seed per acre is the usual amount sown. The crops should be thinned and repeatedly hoed to promote rapid growth and free development.

Turnips are usually washed and bunched in dozens for despatch to market, but the winter crops and also the **Swede turnips** are generally sold by weight and marketed in sacks.

VEGETABLE MARROW (*Cucurbita Pepo ovifera*)—The vegetable marrow is a popular summer vegetable, and although, like all other members of the gourd family, extremely sensitive to low temperature, it can be successfully grown as a field crop in most of the market gardening districts. The principal counties producing the crop are Bedford, Cambridge, Worcester, Cheshire, and the Home Counties.

Varieties—There are two distinct types of the vegetable marrow plant, the trailing and the bush. The most favoured varieties for market are the **Long White** and the **Long Green,** and these may be found in both types of plant. There are many strains of these varieties in existence, but a good market marrow should be of good colour, quite smooth, without pronounced ribs or neck. Such valuable characters as freedom in cropping, good texture of fruit, and earliness in arriving at a marketable size are to be found in the various strains which are commonly grown in the districts mentioned above.

Cultivation—The vegetable marrow crop will pay for good treatment. The plants do best in a deep, cool, loamy soil, which holds the moisture and possesses plenty of organic matter. As the crop does not go into the open ground until late in the season, it can usefully follow a late Brassica crop which was previously well manured, but in any case the land should be deeply ploughed and well cultivated before the marrows are put in, as this will help to retain moisture, and so assist the plants to withstand dry periods of weather. Marrows are sown in the open with safety from the first week of May. The usual practice is to prepare holes about 2 ft. in diameter and 9 ins. in depth, working a little well-rotted manure in each, and leaving each hole filled in to form a shallow mound. These seeds are sown in the form of a triangle 9 ins. apart each way, and when the plants come up and have made the first pair of rough leaves, they are thinned out to leave one plant to each mound. Plants raised under glass may be set out in the same way. Suitable distances apart for the plants are 3 ft., in the case of the bush type, with 4 ft. between the rows, and 4 ft. in the case of the trailing type, with from 8 to 10 ft. between the rows. The land between the latter rows may be intercropped with spinach, turnips, or salad crops.

Vegetable marrows are monœcious plants, and, unlike the cucumber, fertilization is a necessary preliminary to the formation of fruit. Although in the open bees and other insects usually accomplish this, it will help to ensure a good crop, and also an early one, if hand fertilization is practised. The flowers, both male and female, open early in the morning and close when the sun becomes strong, so the grower will find that hand fertilization can be most expeditiously carried out early in the day.

MARKET GARDENING (*Continued*)—

The watering of marrow plants during dry weather should be avoided if at all possible; it is far better to mulch the ground round each plant with short litter.

Marketing—The early crops of marrows, cut when the fruits are about 8 ins. long, are usually wrapped in cabbage leaves and packed in ½ bushel hampers or half "pots" containing about one and a half dozen. Later, when more plentiful, they are sent to market unwrapped in bushel hampers or pots, or in cabbage crates. If the market is near and road transport is utilized, the marrows may be carried loose, but the practice is not to be recommended on account of the damage which may be done to the fruits. All fruits should be cut while quite young, as it will exhaust the plant and force them into an unproductive condition if they are left on too long.

FLOWER FARMING—Great Britain provides what is probably the chief market in the world for flowers. Although vast quantities are imported from continental countries the home production is very much greater, and much capital has been sunk in large ranges of glasshouses entirely devoted to the cultivation of flowers, principally roses, carnations, and chrysanthemums. Thousands of acres of land in Lincolnshire, Cambridgeshire, and Cornwall are now devoted to the cultivation of tulips and narcissi, the Cornish crops of narcissi coming on to the market several weeks before those of any other district.

Apart from these specialist crops which require the provision of expensive glasshouses or peculiar conditions of soil and climate, many fruit growers and market gardeners grow extensive areas of flowers in conjunction with their other crops. The fruit growers of Middlesex and Cambridgeshire raise such crops as pæonies, pyrethrum, statice, gaillardia, and early chrysanthemums between the rows of trees, and such flowers can be very profitable.

HERBS (Garden)—The herbs grown by market gardeners embrace a great variety of plants, but those most in demand are thyme (*Thymus vulgaris*) and sage (*Salvia officinalis*). The aromatic leaves and tops of these hardy, evergreen shrubs are utilized for flavouring soups, sauces, and stuffings, and being in everyday use the demand for them, although limited, is regular. They are both much grown in the neighbourhood of London, sage in particular thriving well on the light calcareous loams of Surrey and Kent. Thyme thrives particularly well in Middlesex. Although large quantities are cut and sent to market as fresh herbs, much of the crops is purchased by herb dryers who specialize in putting up packeted dried herbs.

Thyme, of which there are really two kinds, the **Common Thyme** (*Thymus vulgaris*) and the **Lemon Thyme** (*Thymus citriodorus*), prefers light, warm soils, rather on the dry side, as the latter condition brings out the full aromatic and other qualities of the plant. It may be grown from seed, but is propagated usually by division or laying, and the planting is done in March or April.

There are three varieties of the common thyme—viz., the **Broad-leaved, Narrow-leaved,** and **Variegated,** but only the first and second are grown for market.

MARKET GARDENING (*Continued*)—

Sage succeeds under conditions similar to those required for thyme, but, in common with most of the Labiatæ family, it does particularly well in calcareous loams and in dry situations. Certain districts near London are noted for their crops of sage, which have a high market value. Sage is very seldom raised from seed, and is usually propagated by striking cuttings, taken with a heel, in cold frames in April or May. When well rooted the cuttings are set out in rows 1 ft. apart with 2 ft. from row to row. The young plants should be pinched back frequently to encourage bushiness, and the flower stalks, which appear in August, should be trimmed off. The plants will remain on the same site for several years, and when cutting the growths for market care should be taken to preserve a well-balanced bush. Frequent surface cultivation encourages the production of the new shoots, which are the saleable product.

There are four varieties of sage, but two of them belong to the medicinal category. Those grown for market are the **Common** or **Red Sage** and the **Green Sage.**

Other garden herbs grown by market gardeners, but to a lesser extent because of the more limited demand, are: Fennel (*Fœniculum vulgare*), a perennial aromatic plant employed for sauces; Marjoram (*Origanum* spp.), of which there are two species—one a hardy annual and the other an evergreen shrub; Tansy (*Tanacetum vulgare*), a hardy perennial; Tarragon (*Artemisia Dracunculus*), a tender perennial plant; Borage and Basil.

MARKETING—The marketing of agricultural produce has been defined as the rendering of those essential services which enable the consumer to utilize the products of farms. The most simple form of marketing is the direct supply of goods by the producer to the consumer. Where producers and consumers are in close proximity to one another, agricultural produce is still, to some extent, marketed in this way. The concentration of a large part of the population in urban areas to which food supplies and raw materials have to be brought from varied and often far distant sources has, however, greatly complicated the marketing process. As a result, marketing is nowadays largely carried out by specialist agents; "direct" marketing by individual producers is in the majority of cases either impracticable or uneconomical. Moreover, marketing has come to include a number of subsidiary functions which, according to circumstances, may be essential to efficiency under existing economic conditions.

Marketing Functions—The process of marketing agricultural produce may include any or all of the following functions; (1) Assembling, (2) Grading, (3) Packaging, (4) Processing, (5) Transportation, (6) Storage, (7) Financing, (8) Risk-bearing, (9) Publicity, (10) Selling, (11) Distribution.

(1) *Assembling.*—Assembling is the process of collecting the output of numerous producers into a bulk sufficiently large to enable other marketing operations to be performed economically. Where goods are to be transported considerable distances, or where, for example, grading or some form of processing is to be carried out, pre-

MARKETING (*Continued*)—

liminary assembling secures the economies of large-scale working. Assembling is, moreover, essential to the proper co-ordination of demand and supply, in the same way as the collection of water into a reservoir is necessary to the maintenance of a household water supply, quite apart from any question of storage. Supplies assembled, either directly or through several stages of middlemen, from large numbers of producers, can be co-ordinated with orders representing demand transmitted inwards, again generally by successive stages, from consumers over a wide area.

(2) *Grading*—" Grading . . . consists of sorting a commodity into groups, no two of which overlap, and in each of which the commodity is of practically uniform kind, size, or quality; but a certain range and tolerance are allowed in each grade. Such grading, to be of maximum value, is accomplished through the use of recognized standards. Standardization establishes the permanency of grades and does not allow them to change with the market or from year to year" (Taylor, " Outlines of Agricultural Economics," Macmillan, London and New York, p. 417).

Because of the variability of all agricultural products, grading is one of the most essential operations to efficient marketing. Ungraded eggs, to take but one example, may vary in respect of size, colour, freshness, external condition and internal quality. The commercial advantages of standardization are as follows:

(i.) Standardization is the basis of reliable quality. In purchasing ungraded goods, the buyer inevitably suffers inconvenience and probably loss through a proportion of his purchase being of unsuitable quality. Standardization enables the buyer to rely on securing always the quality of produce required. Buying can thus be reduced to a routine, and this particularly appeals to the retailer, who is thus free to concentrate on selling.

(ii.) Standardized produce can be easily and accurately evaluated. The process of buying and selling is thus facilitated. Where widely accepted standards are in use, produce can be bought on description alone, without the necessity for the buyers seeing the goods beforehand. Such staple commodities as wheat and cotton, for example, for which there are internationally recognized standards, are commonly dealt in on description.

(iii.) The possibility of purchase on description not only facilitates business and thus reduces marketing costs; it also makes for more complete adjustment of demand and supply; the vendor is able to obtain definite price quotations from a number of markets before despatching, and, given free competition, supplies tend automatically to move to those localities where demand is keenest; this makes for price uniformity over wide areas.

(iv.) The possibility of more accurately evaluating standardized goods enables graded produce to realize more nearly its full value. Where high quality and inferior produce are included in the same sample, the market value of the superior produce is disproportionately depressed.

(v.) Standardized produce, because of its ready appraisability, forms a suitable basis for the financing of marketing operations.

MARKETING (*Continued*)—

(vi.) Standardization economizes transport and storage accommodation. Inferior or useless produce is graded out at or near the point of production, and in some instances may be profitably utilized in the manufacture of by-products.

(vii.) Standardization forms the essential basis for advertising in various forms, and for the establishment of a favourable reputation for goods sold under a trade mark or brand name.

Grading may be carried out either by the producer or by a middleman. In certain instances, grading by the producer is the only practicable method; strawberries and some other highly perishable fruits, for example, must be graded by the picker in order to avoid re-handling. With the majority of commodities, however, the output of the average individual producer is too small to enable him to grade efficiently or economically, while in some cases grading may require specialized training such as the producer does not possess—*e.g.*, the grading of wool. Where produce is assembled into a large bulk before grading, skilled operators and special machinery can often be used, grading and packing can be carried out in conjunction—thus reducing handling—a sufficient output can be maintained to produce an economic turnover in each grade, and by-products can be economically utilized. Grading is thus a function which can be advantageously performed by producers' co-operative marketing organizations. Where this is the case, producers are more likely to be paid for their produce according to grading-out results, instead of at a flat rate regardless of quality, and so be encouraged to improve the general quality of the product.

The favourable effect of standardization on the reputation of agricultural produce and its broad social and economic advantages have so far been recognized in recent years that in a number of countries statutory grades have been established for various agricultural commodities to which, in many cases, it is compulsory for produce to be graded before sale, or at least before export. In this country, while the grading of produce is still purely voluntary, statutory grades have been formulated by the Minister of Agriculture for a number of commodities under the Agricultural Produce (Grading and Marking) Act, 1928, and an official mark—the "National Mark"—has been established, applicable only to produce of British origin conforming to a statutory grade and by persons officially authorized to apply the Mark. Voluntary grading and marking schemes for a number of commodities under this Act are now in operation. The efficiency and genuineness of the grading of produce sold under statutory grades and bearing the National Mark are ensured by a Government inspection service.

(3) *Packaging*—The objects of packaging are:

Protection from dirt and damage.
Convenience in handling.
Economy of space, in storage and transportation.
(*d*) Attractive display.
(*e*) The facilitation of trade marking or branding.

MARKETING (*Continued*)—

The principle of standardization is being more and more extended to packaging. Apart from general business convenience, the advantages of the standard package are: reduction of the cost of manufacture of containers, additional economy in storage and transportation space, and the improved presentation of the product. A modern development in wholesale trading is that of the " non-returnable " package—a package which is not returned by the buyer to the vendor and is, in consequence, of the minimum weight and cost compatible with affording adequate protection to the article concerned. The " non-returnable " has the merits of eliminating the inconvenience and costs involved in returning a permanent container, and this, combined with the rapid depreciation and frequent loss of returnable packages and the deterioration of contents often caused by the use of old, damaged, and dirty cases, generally makes the " non-returnable " more economical in the long run.

(4) *Processing*—The marketing of agricultural products may involve the performance of manufacturing or semi-manufacturing processes either (*a*) for the purpose of converting those products into something suitable for consumption, or (*b*) for purposes of preservation.

(*a*) The slaughtering and carcass-dressing of livestock, the milling of wheat, the manufacture of butter and cheese from milk, the brewing of beer, are all essential marketing functions. Requiring, as they do, expensive plant and special technical knowledge, these processes are mostly performed by specialists. One or two of them, *e.g.*, butter, cheese, and cider making—are undertaken by primary agricultural producers, but they are becoming increasingly carried out by the middleman class on a factory scale. This is inevitable in view of the economies in manufacture, uniformity of product, and efficient utilization of by-products resulting from large-scale operations. In certain instances, the first stages of processing may be undertaken by the farmer, and the final stages by the middleman; thus, to save transport costs, milk may be separated on the farm and the cream taken to a factory for butter making; in the production of Gorgonzola cheese, again, the cheese is made by the farmer and is then bought by specialist ripeners for maturing before distribution.

(*b*) Preservation processes include the canning of fruit, vegetables, and meat, the condensation or evaporation of milk, and the " pickling " of eggs. These, again, are very largely " factory " operations when carried out on a commercial scale.

(5) *Transportation*—The methods and organization of transport obviously form a subject outside the scope of the present article. The function of transportation is largely performed, especially in long-range marketing, by specialist carriers—steamship and railway companies, and road transport contractors. In internal trade, the use of road transport for agricultural produce has of late years largely increased at the expense of rail transport, owing partly to the distance of many farms from railway stations and partly to the extra convenience and speed and the reduction of handling generally afforded by

MARKETING (*Continued*)—

the road vehicle. The increase in the number of farmer-owned road motor vehicles and the development of regular local road transport services are important factors in improving the organization of agricultural marketing. Continual progress is being made in cheapening and accelerating transport and in the adaptation of transport vehicles to particular commodities; ventilated and refrigerated railway wagons for perishable produce, for example, are of long standing; modern developments include the provision of glass-lined tanks for the rail and road transport of milk, and of two- or three-tiered motor lorries for transporting small livestock.

(6) *Storage*—The production of most agricultural commodities is seasonal, while consumption is relatively uniform throughout the year. Storage of surplus products at seasons of maximum production, as distinct from the temporary holding of stocks against short-period needs which is an essential part of the distribution process, is therefore essential for the benefit of both producers and consumers. Storage may also be resorted to as a means of carrying over surplus production from one season to another, but in the absence of control over production this is highly speculative. Storage, based on accurate knowledge of supply conditions, both present and future, makes for stability of prices. On the other hand, misguided storage may have the opposite effect. Under the existing "individualistic" marketing system, the incentive to hold agricultural produce in store is largely that of price. Prices at a given moment are influenced, however, not only by the immediate state of supply and demand, but, broadly, by vendors' and buyers' estimates of future supplies. These estimates, being inevitably based on imperfect information, are frequently inaccurate. Hence, in present circumstances, the flow of seasonally produced commodities on to the market is haphazard and not conducive to stability of prices throughout a season.

The development and improvement of refrigeration and preservation processes such as canning, milk condensation and evaporation, or egg preservation, have made it possible to store many products, *e.g.*, meat, butter, eggs, fruit, and vegetables, for longer periods than was previously possible, and have thus had a stabilizing effect on prices. They have also greatly extended the area from which it is possible for importing countries to obtain their food supplies; this has had the effect of intensifying the economic problems of agricultural producers in importing countries.

The storage of agricultural commodities is to a considerable extent undertaken by the farmer. The question of storage accommodation, together with that of finance (see below), largely determines the bargaining strength of the producer in price negotiation; where, through lack of storage facilities, quick sale soon after harvest is inevitable, producers' prices are apt to be unduly depressed. Co-operative ownership of storage facilities by producers has solved this problem in a number of instances.

(7) *Financing*—The complete operation of marketing agricultural produce often occupies a considerable time, particularly where lengthy

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storage periods or long-distance transport are involved. Apart from the cost of physical equipment, capital to the value of all goods in course of marketing is locked up for the whole period occupied by the marketing process. To a certain extent, the necessary marketing finance is provided by the capital of producers and distributors. Shortage of liquid capital on the part of producers, however, frequently, in the case of seasonally produced commodities such as cereals, wool, and to a less extent livestock, leads to flooding of the market by producers, and consequent severe depression of prices, at or near the season or peak of production.

Under certain conditions, marketing operations are capitalized by the advance of temporary loans by banks and other credit institutions on the security of the produce concerned. To be of maximum effect as security for a loan, the produce should permit of ready valuation and should not be subject to rapid deterioration. Thus, wheat, wool, and cotton are eminently suitable commodities for such external financing. The advantages of standardized produce as security for short-term borrowing have been mentioned. A feature of modern marketing finance is the issue, as a basis of credit, of negotiable documents, known as "warehouse receipts," against standardized produce lodged in recognized warehouses.

(8) *Risk Bearing*—Marketing operations involve risks of loss due to the fact that marketing takes time. Two main types of risk may be distinguished—that of loss due to damage or deterioration, and that of price changes. The first can be closely measured, in so far as it relates to damage or destruction by, say, fire or flood, and passed on, at low cost, to a specialist risk-bearing agency—the insurance company; in so far as it relates to loss of quality, the risk, which is naturally greatest with perishable produce, cannot be closely assessed, and must perforce be borne by the market agencies handling the product. The second type of risk—risk of price reduction—can be insured against in the case of standardized non-perishable products by what is known as "future trading." The process of buying for future delivery in order to eliminate risk is called "hedging." Risks like transportation or storage are marketing costs and must be paid for. In some cases the contributing factors can be eliminated or shifted; in others they can be influenced. Broadly, risks can be reduced by better production, better standardization, and better market intelligence.

(9) *Publicity*—Publicity is the stimulation of demand by various forms of advertising and attractive display of produce. Nowadays, the planning of publicity campaigns has become the work of specialist agents. Publicity may be carried out either by individuals on behalf of produce sold under their own trade marks or brand names, or collectively by producers and sometimes distributors on behalf of a commodity as a whole, or a particular section of a commodity, such as the output of a certain district or organization. The well-known "Eat more Fruit," and "Eat more Fish" campaigns in this country, and the extensive advertising of "Sun Maid" products by a Cali-

MARKETING (*Continued*)—

fornian producers' marketing organization, are examples of collective publicity. A recent feature of agricultural marketing is the State financing of publicity carried out on behalf of the produce of particular countries, *e.g.*, the Empire Marketing Board and "National Mark" publicity in this country.

While publicity benefits certain sections of producers and distributors by stimulating the demand for their products, its economic value to the consuming public is often challenged.

(10) *Selling*—The art of selling is one which, under modern conditions, calls for the exercise of considerable skill. It requires accurate judgment as to the best time and the best place to sell, as well as the power of appreciating the personal qualities of the individual purchaser and of influencing his decisions. For the latter reason, salesmanship has become a specialized and often highly paid occupation. The demands of consumers are moulded to a very large extent by the distributor; not only does the retail distributor directly influence the consumer's decision as to the kind and quantity of produce purchased, but the type of goods stocked by the retailer may also be influenced by the wholesale salesman.

(11) *Distribution*—The distribution of farm produce from the ultimate assembly point to the consumer is carried out by two classes of middleman—(*a*) wholesalers, whose function is to distribute goods in comparatively large bulks from central points to retailers, and (*b*) retailers who perform the service of distributing stocks from relatively small local depôts to consumers. This performance of the distributive services in successive stages is a matter of economy and expediency.

In addition to the soliciting of orders for goods, the conclusion of sales, the supplying of credit to buyers, and the delivering of produce to buyers' premises, the distributor's function includes the holding of stocks in sufficient quantity and variety to meet such demands as are likely to arise before fresh supplies can be obtained.

It is common for wholesale, and usual for retail distributors to undertake the distribution of a number of commodities of a somewhat similar nature. This meets the convenience of buyers and makes for economy.

The Market—An important part of the marketing machinery for agricultural produce is the market. The term, in a popular sense, is used to describe any public concourse, at an appointed time, of buyers and sellers of commodities at a place more or less limited or defined. The produce to be sold is, usually, brought to and displayed in the market, and is taken away, after sale, by the buyer. Where the goods are not actually brought to market, but are sold in the market on sample or description, the market may often be referred to as an "Exchange."

The market fulfils two main functions: (*a*) it largely facilitates the co-ordination of supply and demand, (*b*) it facilitates the task of physical distribution.

(*a*) The concourse of large numbers of buyers and sellers at a market

MARKETING (*Continued*)—

enables traders to compare prices offered and asked; prices throughout the area from which the market attracts traders thus tend to be stabilized, and, through the medium of price, supplies are directed geographically in accordance with variations in the keenness of demand from place to place. Where traders in the market deal in "futures," *i.e.*, buy and sell for delivery at some future date—which is only possible with highly standardized produce, the market stabilizes prices and regulates the flow of produce into consumption over a period of time.

For a number of highly standardized agricultural commodities, for which internationally recognized grades are in use, *e.g.*, wheat and cotton, markets or exchanges of world-wide influence have developed, such as the Liverpool and Chicago Wheat Exchanges, or the Manchester Cotton Exchange. Given wide dissemination of accurate market information, the stabilizing influence of a market extends even to non-market transactions effected throughout the area on which the market draws.

(*b*) A market into which is assembled, at frequent intervals, the produce of numerous vendors, enables the buyer to inspect rapidly a large selection of goods and to take delivery of his purchase on the spot. It thus facilitates greatly the distribution of highly perishable and non-standardized produce, where the rapid disposal and frequent renewal of distributors' stocks are essential, and where inspection by the buyer, before purchase, is necessary. Such commodities as livestock, meat, fruit, and vegetables, eggs, poultry, and fish, are, in consequence, very largely sold, at the wholesale stage, through markets. The usefulness of a market in facilitating distribution depends largely on its physical efficiency in respect of situation and construction.

Marketing Organization—As has been indicated, the marketing of agricultural produce is largely effected through the class of agents known as middlemen. Middlemen, contrary to the opinion frequently expressed by producers and consumers, perform valuable services, and the price margin they exact constitutes payment for those services. The existing marketing system is an individualistic one under which prices are determined, production is stimulated, and distribution of produce is regulated by competition between large numbers of individual producers, middlemen, and consumers. Such a system is by no means the most efficient and economical that could be devised. An efficient marketing system is one which secures, for producers, prices sufficient to stimulate the production of goods in adequate quantities and of suitable quality to meet the demands of consumers, and transfers those goods to consumers, as and when required, at the minimum of cost. The existing system does not do this to perfection, largely because of its individualistic nature, partly because the interests of the middleman class, who direct the flow of goods to the consumer and transmit consumer-demand back to the producer, often lie in different directions from those of producers and consumers. The existing marketing system is in many respects too costly; distributive units are often uneconomically small; needless

MARKETING (*Continued*)—

duplication of services and equipment and unnecessary cross-transport occur; produce frequently passes through more hands than is necessary on its way to the consumer. The adjustment of production—in point of quantity and quality—and of distribution to the needs of consumers is far from exact; "over-production" and price instability are common. Where large-scale middleman organizations or "combines" have developed, the interests of producers and consumers may be to some extent endangered through the exercise of monopoly powers by such organizations, although they may be the means of securing more efficient and more economical distribution. The problem of the moment is, therefore, that of securing the advantages of large-scale working and full control of supplies, without the attendant risk of monopoly powers being used contrary to the interest of producers and consumers.

(*a*) *Co-operative Marketing*—Realization of the deficiencies of the existing marketing system has stimulated the formation of co-operative organizations of producers for marketing purposes. Such organizations do not necessarily assume the whole of the marketing functions; they may be formed only for the purpose of carrying out a few stages in the marketing process, such as assembling, grading, and packing. Co-operative marketing is advantageous only if it performs its functions more efficiently than the system which it replaces. This fact has sometimes been lost sight of. The motive which has stimulated the formation of co-operative marketing associations has often been merely the assumption that excessive profits were being made, at the producers' expense, by middlemen. As a result, such associations often merely replaced a middleman system without any resulting economy and sometimes with reduced efficiency.

There are, however, functions which co-operative marketing associations can perform with advantage. Where a large organization replaces numerous small private traders, the economies of large-scale operations are obtained. In other instances, co-operative associations may undertake marketing functions, of great value to the producer, which might otherwise not be performed at all, simply because middlemen have little or nothing to gain from their performance. Thus, co-operative societies for the purpose of grading and packing members' produce, especially where produce is pooled and paid for by grade at a price based on the proceeds of sale of each grade, can effect great improvements in the quality of production and in the demand for their members' produce. Co-operative societies, again, can undertake various forms of processing of farm produce; thus co-operative creameries, bacon factories, beet-sugar factories, and abattoirs are features of agricultural marketing in various countries. It does not follow that such societies can perform these processes with any greater efficiency or economy than independent enterprise, but here again there have been instances where the initiation of subsidiary manufacturing industries of great benefit to agriculture has waited upon collective action by producers themselves. Similarly, the development of an export trade in an agricultural commodity may be the work of

MARKETING (*Continued*)—

co-operative export societies. The co-operative ownership, by producers, of storage facilities, *e.g.*, the co-operative elevator societies of America, removes the bargaining weakness to which producers are liable where farm storage accommodation is deficient. Co-operative marketing societies, again, provide a satisfactory basis for the financing of marketing operations by external agencies, and this, in turn, strengthens the bargaining position of producers.

At the consumers' end of the marketing chain, co-operative organizations of consumers have assumed the function of distribution, and a feature of agricultural marketing to-day is the growth of inter-trading between producers' and consumers' co-operative organizations.

(*b*) *Marketing Boards*—While local associations, or societies controlling a part of the output of a commodity in any district, can often effect considerable improvements in marketing, complete "rationalization" of marketing is only possible where there is centralized control, on a commodity basis, of the whole output of a producing area. This has been realized, particularly in the U.S.A., where large-scale regional federations of local marketing associations have gradually developed for a number of commodities, *e.g.*, the California Fruit Exchange, Minnesota Co-operative Creameries, etc. Such organizations may effect standardization of grading and packing on a wide scale. They may carry out widespread commodity advertising, which requires for its initiation the support of producers as a whole. They may conduce to the stabilization of prices by regulating the flow of produce on to the market, or by directing its geographical distribution to meet variations in demand; the operations of such organizations in the former respect, however, have in practice often increased price instability owing to their proceeding on insufficient knowledge of supply conditions. They may check "over-production" by regulating their members' output either directly or through the medium of differential prices for "surplus." Where "over-production" has occurred, they may prevent or minimize its evil effects by the control of "surplus"—dictating the quantity or quality of produce which shall be marketed and determining the method of disposal of the balance—where under an individualistic system such a "surplus" would be thrown into distribution and would spoil the market for the whole output. Such organizations may promote the interests of producers in their contact with external agencies, in a number of directions, as, for example, the securing of favourable terms from transport companies or the regulation of trade practices by negotiation with middleman organizations. Organizations of this type may not necessarily perform any buying or selling; they may merely act as "boards of major strategy" regulating the passage of produce through the ordinary marketing channels, as is the case with, for example, the New Zealand Dairy Produce Control Board, or the British Columbia Interior Committee for the marketing of fruit.

Certain types of action open to centralized commodity marketing organizations depend for success on the collaboration of all producers

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of the commodity concerned. In particular, measures aimed at the prevention of "over-production" or of its depressing effect on prices, or price agreements arrived at by collective negotiations with the distributive trades, may be entirely nullified by the failure of a small minority of producers to support the action of the organized majority. Again, the formation of such organizations may often hang fire owing to the apathy of a section of producers. In a number of countries, *e.g.*, New Zealand, the Australian Commonwealth, Queensland, New South Wales, British Columbia, South Africa, legislation has, in consequence, been passed providing for the constitution, given the approval of a stated majority of producers of the commodity concerned, of statutory commodity "Marketing Boards," with power to compel the adherence of all producers to their policy, or, alternatively, bestowing similar powers on existing co-operative organizations. The future organization of agricultural marketing would appear to lie in the growth of a system of such comprehensive "Boards," either merchanting or solely regulatory, acting as strong business executives for the various agricultural commodity industries, and leaving producers free to devote their whole attention to their producing activities.

A. W. S.

MARL—Marl is a clay containing variable quantities of carbonate of lime, and it used to be applied to land by the process of "marling," which is done in much the same way as "claying." Marling is rarely carried out to-day, as it is too expensive a method of correcting soil acidity and reclaiming poor land.

The best-known examples of marl deposits in Britain are those of the Middle Lias, the "Malm" and chalk marl of the Cretaceous System, and the New Red Marl of the Lias. Marling must necessarily be carried out only on land near marl beds; it is carted and spread on the land at rates varying from forty to eighty cartloads per acre. Many acres of sandy, gravelly and peaty soils have been reclaimed by marling, and where it has been done properly the improvement effected on the soil has been permanent.

MASHLUM—See Dredge Corn and Mashlum.

MEADOW HAY—For feeding value and conditions affecting the same see Food and Feeding, Scientific Aspects of; also Feeding Stuffs for composition and manurial value.

MEAT—For methods of preservation by refrigeration see Refrigeration.

MEAT MEAL—For composition and feeding value see Feeding Stuffs, and Poultry Nutrition; for value as a manure see Fertilizer.

MENDELISM—Although Mendel published his laws of heredity in 1866, their importance was not appreciated at the time and no notice was taken of them until 1900, when De Vries, Correns, and Tschermak simultaneously brought them to notice. Their value was recognized immediately, not only because they made the scientific study of

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heredity possible, but because they laid emphasis on discontinuity in variation, and the belief that evolution was a discontinuous process was then gaining ground.

Mendel's success was due largely to the care and accuracy with which his experiments were carried out. He worked on the edible Pea (*Pisum sativum*), a self-fertilized plant, and concentrated his attention on following the inheritance of single characters, not on a general resemblance due to a number of characters; and he ascertained by preliminary observations that his parent varieties were breeding quite true for the characters whose inheritance he wished to follow. For example, he crossed a tall variety, about 6 or 7 ft. high, with a dwarf variety, about 1 ft. high. The hybrids, the F_1 generation as it is called, were all tall; consequently tallness is said to be *dominant*, and dwarfness *recessive*. These F_1 plants were self-fertilized to give the following generation, the F_2, which was found to consist of both tall and dwarf plants in the proportion 3 tall : 1 dwarf. When self-fertilized, the dwarfs bred true and were exactly like the dwarf parent so far as stature was concerned; while of the talls one-third of the number bred true to tallness, like the tall parent, and each of the remaining plants gave rise to both talls and dwarfs, like the F_1. The true breeding talls and dwarfs, *i.e.*, those which produced only talls and dwarfs respectively, are said to be *homozygotes*; and the impure talls, *i.e.*, those which gave rise to both talls and dwarfs, are said to be *heterozygotes*. The F_2 therefore consists of three kinds of plants as follows:

$$\underbrace{\begin{array}{c}\text{1 tall homozygote}\\ \text{(breeding true)}\end{array} \; : \; \begin{array}{c}\text{2 tall heterozygotes}\\ \text{(splitting into 3 tall : 1 dwarf)}\end{array}}_{\text{3 dominants (tall)}} \; : \; \begin{array}{c}\text{1 dwarf homozygote}\\ \text{(breeding true)}\\ \text{1 recessive (dwarf)}\end{array}$$

In explaining these results Mendel suggested that the original tall parent, which derives tallness from both its parents, could be written TT, and the original dwarf parent, tt; while the F_1, which derives tallness from one parent and dwarfness from the other, would be Tt. He then supposed that the F_1 contained either T or t in its germ-cells, in the proportion 1T : 1t. The F_2 would be produced by random matings between the male and female germ cells, female (1T+1t) ×male (1T+1t), and would therefore consist of 1TT+2Tt+1tt, which in their turn would breed in the way described above. T and t, the factors for tallness and dwarfness, are said to be *allelomorphs*; and the process by which T and t, present together in the F_1 plants and in the heterozygotes of the F_2 generation, separate intact and pass to the germ cells, which contain either T or t, is called *segregation*. It is now generally accepted that this segregation of the members of an allelomorphic pair is effected by the chromosomes at the reduction divisions of the heterozygote (see Cytology); and it is important to note that T and t behave as constant units in no way changed, or contaminated, by their presence together in the heterozygotes.

In cases such as the one described, where dominance is complete, the heterozygotes cannot be separated by their appearance from the pure dominants, and a 3 : 1 ratio is therefore obtained in F_2. Such

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cases are frequent; but it is perhaps equally frequent that the F_1 is intermediate, as in crosses between red and white flowered *Mirabilis jalapa*, wherein the F_2 consists of 1 red : 2 pink : 1 white flowered. Again, in crosses between six-rowed and two-rowed barley F_1 is intermediate and F_2 consists of 1 six-rowed : 2 intermediate : 1 two-rowed; the intermediates varying, or fluctuating, almost from six-rowed to two-rowed so that their separation from the parent forms needs care; but all these intermediates breed the same, giving 1 : 2 : 1 again, whether they approach six-rowed or two-rowed in appearance.

Mendel himself showed that a number of other characters in the Pea are inherited like tall and dwarf, and that if two or more pairs of characters are involved in the same cross they are inherited independently. Thus, if a Pea with round yellow seeds is crossed with one that has wrinkled green seeds the F_2 generation consists of 3 yellow seeds : 1 green, and among the yellow seeds or among the green there will be 3 wrinkled to every 1 that is round, so that F_2 consists of 9 yellow round : 3 yellow wrinkled : 3 green round : 1 green wrinkled, thus:

$$\begin{array}{rl} F_2 = 12 \text{ yellow} & \begin{cases} 9 \text{ round.} \\ 3 \text{ wrinkled.} \end{cases} \\ 4 \text{ green} & \begin{cases} 3 \text{ round.} \\ 1 \text{ wrinkled.} \end{cases} \end{array}$$

From this cross we have therefore obtained the new combinations round green and wrinkled yellow. This recombination of characters forms the basis of plant breeding, in which the object is to combine as many desirable characters as possible in a single individual; thus from the cross high yield but low quality by low yield but high quality an attempt would be made to get plants combining high yield with high quality.

In the cases described, development of a character is dependent on a single factor, *e.g.*, T or t. That a character might depend on two or more factors was first shown by Bateson and Punnett, who obtained a purple-flowered F_1 from a cross between two white-flowered Sweet Peas. F_2 consisted of 9 coloured : 7 white, and further analysis showed that two factors, R and C, were necessary to produce colour. One of the white-flowered parents, RRcc, contained the first of these but not the second; and the other, rrCC, contained the second but not the first. F_1 would be RrCc; and R and C are inherited independently just like any other pairs of factors, the gametes formed being 1RC+1Rc+1rC+1rc. It is not necessary to describe further how the ratio 9 : 7 arises, but it may be stated that various other ratios can be obtained when a two-factor scheme of inheritance is followed, since the ratio depends upon whether the factors are dominant or recessive, and how they co-operate to produce their effect.

Investigation has shown that many characters in plants and animals depend for their development on two complementary factors; indeed three or even more factors may be necessary. Thus the factor B turns red-flowered Sweet Peas to purple: BBRRCC is purple; bbRRCC

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is red; bbrrCC, bbrrcc, etc., are white; so that three factors are necessary for the purple colour to develop. Series of this sort have been worked out for flower colour in several plants and for coat colour in animals.

It often happens that characters are inherited quite independently as in the case of the colour and wrinkling of Sweet Pea seeds; but some characters, instead of being independent, show linkage. This was first discovered by Bateson and Punnett in a cross between two varieties of Sweet Peas, one with round, the other with long pollen. This pair of characters gave a 3 : 1 ratio in F_2, showing that they were inherited in simple Mendelian fashion; but the factors L (long pollen) and B (purple flowers) were associated, so that when B and L entered the cross together they tended to remain together, and the F_1 gametes were produced in about the proportions 7BL+1Bl+1bL+7bl instead of 1BL+1Bl+1bL+1bl. Consequently, the F_2 contained an excess of the two parental combinations, purple flowers with long pollen and red flowers with round pollen; while the two new classes, purple round and red long, were greatly in defect.

This phenomenon is widespread; and it is now generally accepted that two factors will be linked when both are carried by the same chromosome. So that when a sufficient number of factors are studied, they are found to fall into a number of linkage groups equal to the number of chromosomes in the gametes of the species concerned. (See Cytology.)

In general it may be said that Mendelism has shown that the differences between different forms of life are due to constant units, the factors, which determine how the characters of an organism will develop. In the higher plants and animals each organism contains these units in pairs, and one member of each pair is distributed to the germ cells.

The classification of variations has been simplified greatly by the Mendelian conception. Thus, maize seeds show great variability as the result of differences in colour and composition. But the situation is made much clearer when it is realized that this variability is due to different combinations of a comparatively small number of variable characters: the endosperm may be starchy or sugary in composition, and yellow or white in colour; and superimposed on these changes the aleurone layer may be coloured or colourless, and if coloured may be either purple or red. In general, the plant breeder or geneticist, confronted with a variable population, attempts to reduce confusion to order by classifying the variations as far as possible in this way.

Analysis of variation was made still more exact by Johannsen's theory of pure lines, published in 1903. It can be concluded from Mendel's discoveries that if self-fertilization is continued for a sufficient number of generations the individuals obtained will be homozygous for all factors; and ought, therefore, to breed absolutely true. Johannsen, working on the variation in seed weight of Beans (*Phaseolus vulgaris*), found that this was actually the case. Selecting individual

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plants from a commercial variety of the Bean, and growing their progeny for six generations, he was able to establish a number of pure lines, each with a different average seed weight. Selection within one of these lines had no effect, for the average weight of the produce of the largest seeds was the same as the average weight of the produce of the smallest seeds, and both values were the same as the average for the parent line from which they came. The lines were, in fact, quite constant. His original selection within the commercial variety was successful because the commercial variety was a mixture of different pure lines; in fact, the average seed weight of the lines he isolated from it ranged from 35 to 64 centigrams ("Über Erblichkeit im Populationen und reinen Linien," Jena, 1903).

Johannsen's conception is accepted in all breeding work with self-fertilized plants, the aim in such cases being to produce the best pure line. In most cases this principle is undoubtedly a sound one, and has added importance in crops such as barley, in which uniformity is itself a valuable feature. (See Barley.) In practice, however, it is often difficult to obtain a pure line because the breeder usually tries to raise his new variety from a cross and therefore begins with individuals that are heterozygous for many factors. Under these circumstances self-fertilization must be continued for many generations before the breeder can be confident that the plants he picks out are completely homozygous. And although, wishing to produce his variety within a reasonable period, he accelerates matters by discarding lines that are not breeding true, it is difficult for him to be certain that his selections are not segregating for some inconspicuous character.

Inheritance on Mendelian lines has been shown to be general in both the plant and animal kingdoms, and to apply to characters of the most varied description. As examples, mention may be made of flower colour, as in the Sweet Pea and many other plants; leaf shape, *e.g.*, *Primula* (R. P. Gregory, D. De Winton, and W. Bateson, *J. Genetics*, xiii., 219-253, 1923); resistance to disease, *e.g.*, Wheat (R. H. Biffen, *J. Agric. Sci.*, ii., 109-128, 1907); the composition of the endosperm of seeds, as in Maize; the coat-colour of various animals; and the type of comb in Fowls. An interesting case is provided by lethal factors, which cause the death of individuals containing them. These are probably important in animal breeding, since they appear to be widespread in many breeds, their effect being shown in cases of abortion, or of still-born monstrosities, etc. (C. Wriedt and O. L. Mohr, "Amputated, a Recessive Lethal in Cattle; with a Discussion on the Bearing of Lethal Factors on the Principles of Live Stock Breeding," *J. Genetics*, xx., 187-215, 1928). A good example is the Dexter breed of cattle, which are heterozygous for a lethal factor L, and therefore produce 25 per cent. of still-born "bull-dog" calves, LL. The Dexters themselves, Ll, owe their distinctive differences from the Kerry to the presence of this factor in heterozygous condition, the relation being Kerry = ll, Dexter = Ll,

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"bull-dog" calf=LL. The Kerry being without L does not, of course, produce these monstrosities. (For literature see O. L. Mohr and C. Wriedt, *J. Genetics*, xix., 315-336, 1928.)

It is now known, in those cases where infertility does not entirely prevent analysis, that Mendelian inheritance holds not only for crosses between varieties of the same species, but for crosses between different species; and geneticists usually assume that the inheritance of every character is Mendelian, although various circumstances may sometimes make analysis difficult. If we except special cases, such as the inheritance of plastids, this belief implies the single assumption that the germ plasm is made up of constant units; for it is now well established that segregation, the other essential to Mendelian inheritance, is effected by the chromosomes (see Cytology), and is therefore subject to whatever irregularities may affect chromosome behaviour. There is certainly good evidence for this view, but there seem at present to be two directions in which present ideas may need elaboration or modification, when more is known. First, it is obvious that the Mendelian method only allows us to study the differences between closely related types, and tells us nothing about all the more fundamental characters that are common to the two forms crossed. In this direction further knowledge is being gained by the study of crosses between species that yield hybrids which are partially, but not completely, sterile, and by related methods. Secondly, too little is definitely known about inheritance of the so-called quantitative characters, such as yield or size.

If the size of an organ be measured it will be found in a mixed population to vary almost continuously between two widely different extremes, as Johannsen found, for example. Part of this variability is due to fluctuation, genetically identical individuals giving somewhat different values because they had developed under somewhat different conditions. The remaining differences are genetic, and must be large in number since it is possible to isolate many pure lines from such a population. The size of the organ is therefore thought to be controlled by many factors, cumulative in their effect; lines with mean sizes of 10 and 30 differing perhaps by as many as 10 factors, each having an effect of from 1 to 3 say, so that many intermediate lines could exist. It is often thought that support for this view is afforded by Nilsson-Ehle's demonstration that grain colour and chaff colour in wheat (*Triticum vulgare*) depend on 1, 2, or 3 factors acting cumulatively; but actually there are reasons for regarding this as a special case (see Cytology) from which general conclusions cannot be drawn. Indeed, although it has been shown that size differences may be inherited in Mendelian fashion (E. W. Lindstrom, "Linkage of Size, Shape, and Colour Genes in Lycopersicum," *Zeit. f. Indukt. Abst. u. Vererbungs. Supp. Bd.* ii., 1031-1057), the cumulative factor theory of its inheritance has never received a really adequate genetic test, although it is clearly a reasonable view, agreeing with the facts at present known.

Plant and animal breeders are familiar with the fact that a new

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form may occasionally appear as a sport. In plants this may be as a bud-sport or as a seedling. Thus, horticultural literature records instances where a peach tree produced a branch of the nectarine as a bud-sport; and most of the varieties of *Primula sinensis* now grown probably arose from the original type as seedling sports. Such sports, or mutants, have often been recorded in genetic literature and usually involve a single factor; while in the great majority of cases the new form is recessive to the old.

Not only is it almost universal that a new mutant is recessive; but it is also found almost invariably that the presence of a character is dominant to its absence, coloured flowers being dominant to white flowers for example. These facts are explained most easily by the Presence and Absence Theory of Bateson and Punnett, according to which the recessive lacks a factor which is present in the dominant, plants with white flowers lacking the factor necessary to produce coloured flowers. On this view factor mutation is nearly always loss of a factor. It may be doubted whether a recessive factor should be regarded as complete absence, but it certainly seems likely that recessives lack something which is present in the dominant. Confirmatory evidence is given by multiple allelomorphs—series of three or more factors of which any two are allelomorphic to each other, the different members of the series affecting the same character and producing effects that differ only in degree. Thus, W_1, W_2, and W_3 are three multiple allelomorphs affecting the "eye" of the flower in *Primula sinensis*. In W_1W_1 the whole petal is white; in W_2W_2 there is a yellow eye; in W_3W_3 the yellow extends over about half the petal; and if any two of these forms are crossed a 3:1 ratio is obtained, since any two of the three factors are allelomorphic to one another. This situation clearly suggests that the three factors should be regarded as differing in a quantitative manner, with W_2 as the middle term in the series (W. Bateson, "Segregation," *J. Genetics*, xvi., 201-235).

The most important modern developments of Mendelism arise from the theory that the factors are carried by the chromosomes. (See Cytology.)

General References.—W. Bateson, "Mendel's Principles of Heredity," 413 pp., Cambridge, 1913; R. C. Punnett, "Mendelism," 219 pp., London, 1919; E. B. Babcock and R. E. Clausen, "Genetics in Relation to Agriculture," 673 pp., New York, 1927. A. E. W.

METABOLISM—The chemical changes going on in a plant or animal body, regarded, not severally, but as a whole. A substance produced by these changes may be referred to as a *metabolite*. Changes leading up to the building up of tissue are grouped and called processes of *anabolism*, while those of breaking down tissue are processes of *katabolism*. The terms *anabolites* and *katabolites* are used in an analogous way to metabolites.

METABOLISM, MINERAL—Apart from the purely organic substances present in feeding stuffs and the bodies of animals (proteins, fats, and

METABOLISM, MINERAL (*Continued*)—

carbohydrates), a considerable number of chemical elements are present. These elements are often recovered in an inorganic form in the ash obtained by incinerating these materials, and are therefore included under the general term "ash constituents" or "mineral ingredients," although they may be present in the original material in organic combination. Thus, sulphur and phosphorus, which are generally present as sulphates and phosphates in the ash of a food or animal tissue, are partly derived from the proteins present in the original material, in which they are present in organic combination. Calcium, sodium, potassium, magnesium, iron, phosphorus, sulphur and chlorine are all present in living material, together with minute traces of iodine, fluorine, copper and zinc, and these "inorganic constituents" are as essential for the maintenance of the vital processes as are the better known organic substances.

Owing to the special difficulties associated with any attempts to elucidate the part played by these substances in the normal growth processes, the study of these substances in the normal metabolism of animals has to a large extent been neglected, and it is only within recent years that research workers have begun to pay particular attention to problems of mineral metabolism. The work of the Rowett Research Institute, under the direction of Dr. J. B. Orr, has focussed the attention of workers in the field of Animal Nutrition on the importance of the study of these substances, and their vital importance in animal nutrition (see *The Rowett Research Institute, Collected Papers*, vols. i. and ii.).

The difficulty of study is largely associated with the fact that the paths of excretion of the mineral constituents of a diet are partly fæcal in nature and partly urinary. In addition, there is often a considerable delay in the excretion of mineral substances, following their administration in a diet, and the nature and character of the behaviour of an individual ingredient is materially influenced by the presence of other inorganic constituents in the diet, and by the previous nutritional history of the experimental animal. For these reasons, conclusions reached from "balance" experiments are often untrustworthy, and must, in the absence of other corroborative data, be treated with considerable reserve. Perusal of the literature on metabolic studies of mineral constituents at once brings out this point, and in the opinion of the writer progress in our knowledge of mineral metabolism can be more surely obtained by studies based on the animal cell and tissue itself, rather than studies on the living individual.

The Function of Mineral Constituents—The mineral elements of the body occur as normal constituents of the skeletal and soft tissues of the body. In the case of the skeleton they are present partly as inorganic salts and partly in organic combination; in the soft tissues they are present largely in organic form. They also occur, mainly as inorganic salts, in the plasma and fluids surrounding the soft tissues of the body. The efficiency of the normal physiological processes of the animal cell is largely dependent upon the maintenance of a

METABOLISM, MINERAL (*Continued*)—

suitable concentration of inorganic salts in the cell solution itself and the fluids surrounding it, and any condition which alters this concentration leads to immediate impairment of the function of the cell itself or the fluids produced by it. As Ringer demonstrated in 1882-83, the presence of calcium is necessary for the contraction of heart muscle, and Locke in 1894 showed that the transference of the excitatory process from nerve to muscle only occurs in the presence of calcium salts. Enzymes are often inactive in the absence of electrolytes. Bertrand (1912) demonstrated the enormous importance of minute traces of zinc and iron on the growth of the mould *Aspergillus*, and the influence of small traces of manganese on its fructification and the production of conidia. The reverse effect of small traces of copper on the growth of *Spirogyra* was noticed by Nägeli in 1893, and corroborated later (1895) by Locke on tadpoles. Nägeli found that a solution of copper in distilled water (1 part in 77 millions) killed *Spirogyra* in one minute, and Locke found that minute traces of copper in distilled water were toxic to tadpoles. This latter action of minute traces of the compounds of various heavy metals is known as "oligodynamic action," and has been used for controlling the growth of surface weeds in certain American inland lakes. The examples given above will suffice to demonstrate the absolute necessity of the supply of mineral constituents to the living animal; not only are these substances essential for the adequate functioning of the living cell, but their presence in very minute traces often leads to profound effects. Not only do mineral constituents play an important part in giving strength and rigidity to the skeletal structures, they also maintain the body fluids in the condition necessary for the functional activity of cells, and by their physico-chemical properties neutralize the acidity of the blood caused through the production of acids during katabolism. Some of them, at least, form essential ingredients of body fluids. Thus, iron forms an essential constituent of hæmoglobin, the red colouring matter of the blood, and iodine is an essential constituent of "thyroxin," the active constituent of the thyroid secretion. In brief, life without mineral constituents is impossible.

The Distribution of Ash in Tissues and Fluids of the Body and the Feeding Stuffs—In the animal body, approximately 5 per cent. of the fat-free empty weight consists of ash, and nearly 80 per cent. of this amount is contained in the bones.

TABLE I.

ASH CONTENT OF VARIOUS SUBSTANCES OF ANIMAL AND PLANT ORIGIN, CALCULATED IN PERCENTAGES OF DRY SUBSTANCE.

Dry Substance.	*Ash, per Cent.*		*Ash, per Cent.*		*Ash, per Cent.*
Fat-free bone	50-66	Oats	3·7	Meadow hay	7·2
Fat-free lean meat	5·6	Maize	1·5	Oat straw	5·7
Pig's blood	4·2	Wheat	1·7	Wheat straw	7·1
Ox liver	5·5	Rice	0·9	Mangolds	6·8
Ox thymus	6·2	Linseed	4·0	Pasture grass	10·5

METABOLISM, MINERAL (*Continued*)—

The figures given in Table I. illustrate the relatively high proportion of ash present in the skeletal structures of the animal, and demonstrate that the ash of plants is to a large extent present in the vegetative parts rather than in the seeds. The chief distinction between ash of animal and plant origin resides in the fact that ash of plant origin is relatively high in silica. Owing to this essential chemical difference between plant ash and animal ash, the percentage of ash present in a plant is of little value as a guide to its value for animals, unless it is supplemented by a knowledge of its component parts.

It has been shown that the functions of the ash in the skeletal structure and the soft parts of the body are materially different, and it becomes of interest to ascertain to what extent these ashes differ in composition.

TABLE II.

DISTRIBUTION OF "MINERAL" ELEMENTS IN ASH OF ANIMAL ORIGIN (IN PERCENTAGES).

	CaO.	MgO.	K_2O.	Na_2O.	P_2O_5.	Cl_2.
Bone ash	51·3	1·1	0·2	1·1	37·5	0·04
Ash of lean beef ..	1·1	3·6	37·8	8·1	45·0	4·5
Ash of human muscle	0·9	3·7	35·8	10·1	43·1	6·4

These analyses clearly illustrate from a quantitative standpoint the important part played by calcium and phosphorus in the formation of bone, and the relative unimportance of potassium, sodium, and chlorine.

In the case of flesh formation, calcium appears to be relatively unimportant, whereas potassium, chlorine, sodium, and phosphorus play an important rôle. Phosphorus in both cases is an important constituent, but even in this case a major difference exists that is not revealed by the analysis, the phosphorus in bones being present mainly as calcium phosphate, whereas in meat it is largely present in an organic form. It is important to realize that the analysis of an ash taken by itself can be very misleading, and in many cases can be quite fallacious as a guide to the principles of feeding.

The Sources and Nature of Supply of Ash Constituents to the Body—The ash constituents of the body are obviously derived primarily from the food constituents. As the analyses already given reveal, the intake of food by the animal leads to the consumption of varying amounts of ash. In the case of protein, fats, and carbohydrates, the relative digestibility of these constituents is easily obtained, but in the case of ash ingredients, this is not possible owing to the fact that the alimentary canal forms one of the paths of excretion for these substances. On account of this, it is extremely difficult to obtain accurate knowledge as to what happens to the mineral ingredients of a ration during digestion, and such scanty knowledge as we possess

METABOLISM, MINERAL (*Continued*)—

has been obtained chiefly by chemico-histological methods and by means of experiments carried out on isolated portions of the alimentary tract.

Nature of Supply of Ash Constituents—During incineration of a food material, drastic chemical changes occur to the mineral ingredients, and the form in which an ingredient is recovered in the ash is generally materially different from its original constitution. Such knowledge as we possess of the nature and constitution of the mineral ingredients is derived from consideration of the original material itself. Thus, chlorine is mainly present in the original food materials as chlorides, sulphur to a minor extent as sulphates, but mainly in organic combination as a constituent part of proteins, and iodine and fluorine are mainly present as iodides and fluorides. Phosphorus is present both in an inorganic form as phosphates, and also in an organic form in proteins and certain classes of fatty materials and carbohydrates. Iron and magnesium also occur as inorganic salts and in organic combinations. The metals are generally present in food materials as salts of hydrochloric, sulphuric, phosphoric, and organic acids.

Digestion and Absorption of Ash Constituents—It has been experimentally demonstrated that soluble salts readily pass in solution through the intestinal wall. The rate of absorption is not in strict accordance with the laws of diffusion, the cells of the intestinal epithelium apparently exercising a selective influence. Wallace and Cushny (*Amer. J. of Physiology*, vol. i., p. 411) have investigated the relative absorbability of salt solutions, and have placed in four main groups the commoner salts, according to their relative ease of absorption by the intestine. Chlorides, iodides, bromides, and the salts of the lower fatty acids are most readily absorbed; next follow nitrates, lactates, salicylates, and ethereal sulphates. Inorganic sulphates, phosphates, citrates, tartrates, malonates, and malates, on the other hand, are absorbed with great difficulty. From this it would appear that chlorine, iodine, and the metals readily reach the general circulation if presented as inorganic salts, but sulphur and phosphorus are not readily absorbed in the form of inorganic salts. The beneficial effect following calcium phosphate feeding shows, however, that phosphates are absorbed to a considerable extent, and work carried out by Zuckmayer gives a clue to the possible mechanism of the process. Zuckmayer found that tricalcium phosphate administered in the form of a fine suspension was not absorbed at all, but if administered as a colloidal aggregate with protein it was readily absorbed. Thus, calcium phosphate fed to an animal would react with the acids of the stomach and pass into solution. On reaching the intestine and coming in contact with the alkaline fluids there present, the calcium phosphate would be reprecipitated in the form of a fine suspension, and would react with the protein cleavage products produced during digestion to form a colloidal aggregate, and in this form would undergo absorption. This hypothesis is an attractive one, since it would account for

METABOLISM, MINERAL (*Continued*)—

the fact that in the large intestine tricalcium phosphate is an excretory product and is not reabsorbed, since by the time the large intestine is reached, the protein cleavage products resulting from digestion have already been absorbed, so that one of the requisite conditions for the absorption of tricalcium phosphate is absent. With regard to the digestion and absorption of ash constituents in organic combinations, the two elements of importance are sulphur and phosphorus. Sulphur is present in proteins as a constituent part of the amino-acid cystin, and is therefore readily absorbable in this state. Indeed, the absorption of sulphur by the intestine has been proved to follow very closely the absorption of protein, thus proving that the main source of sulphur to the animal body is that contained in proteins, and that inorganic sulphur is practically valueless. Phosphates are present in organic combinations in foods as phosphoproteins, nucleoproteins, phospholipins, and phytin. The phosphorus of phosphoproteins is absorbed either in the form of "phosphopeptone" or inorganic phosphate, that of nucleoproteins in the form of nucleins, that of phospholipins partly as lecithin and partly as glycerophosphates, and that of phytin as phytates produced by the action of phytases present in the original food material.

The Normal Requirement of Ash Constituents—Very little is known as to the normal requirements of animals for ash constituents; such figures we possess being estimates obtained by analysing the bodies of animals at different stages of growth, calculating from the figures so obtained the normal daily storage, and multiplying this daily storage by an arbitrary figure in order to provide for factors adversely affecting assimilation from the food intake. Orr (*The Rowett Research Institute, Collected Papers*, vol. ii., p. 471), from consideration of the data given by Sherman and Hawley in 1922, in an investigation on the assimilation of calcium and phosphorus by school children, assesses this figure at three times the storage figure. It is interesting to note that Wolff ("Farm Foods," p. 276, 1895) states that "the food of young animals reared artificially should always contain two to three times as much lime and phosphorus as that actually required by the animals." By this method Orr estimates that the ration of a young calf should contain 1½ ozs. of lime a day, a young pig ¾ oz. a day, and a cow giving 4 gallons a day 3 ozs. In view of the differential retention of ash constituents according to metabolic condition, and the interaction of one constituent with another, it is almost impossible to express the needs of animals for ash constituents in terms of quantitative formulæ, as has been done with protein and energy. Thus, in a metabolic experiment with pullets, the writer found that during the non-laying period the utilization of the calcium of the food was 15 per cent., whereas during egg laying the utilization increased to 41 per cent. (Halnan, *J. Nat. Poult. Inst.*, vol. x., No. 9, 1925). Ingle (*J. Agric. Sci.*, vol. iii., p. 22) calls attention to the fact that prolonged dieting on a ration in which the phosphorus was in considerable excess of the calcium led to ill effects, and suggests that "bran disease" is due to this cause. Elliot,

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Crichton, and Orr (*Brit. J. of Exptl. Path.*, vol. iii., No. 1, Feb., 1922) induced rickets in pigs by feeding them on a diet badly balanced for phosphates and calcium (P_2O_5 : CaO—3 : 1), whereas on a well-balanced diet (P_2O_5 : CaO—1 : 1) no ill effects followed. These experiments emphasize the difficulty of attempting to express the normal requirements of animals for ash constituents, since not only does the utilization vary within very wide limits, according to metabolic condition, but the metabolism of the animal also appears to be affected unless the ratios between the ash constituents are maintained at certain predetermined levels. Analysis of the bodies of animals at different ages and at different levels of production is useful since it affords knowledge of the times at which ash constituents need to be given in the food, and gives data upon which the *minimal* requirements of the animal can be calculated. Similarly, analysis of the materials produced by animals (milk, eggs, etc.) also gives us information as to the nature and proportion of ash ingredients to be added. It does not, however, afford us the information we need as to the quantitative requirements, and it is doubtful whether such knowledge can ever be attained, except under well-defined conditions of dietary. The useful information that is required is, firstly, the minimal mineral requirements of the animal at different stages of production; secondly, the stage at which excess of minerals in the food leads to pathological conditions; and, thirdly, the optimum ratios for the supply of mineral ingredients in a food. Thus Mitchell and Carman (*J. Biol. Chem.*, lxviii., 165, 1926) found that the addition of 1 per cent. salt to a ration consisting of maize 86 parts, casein 10, cod-liver oil 2, calcium carbonate 1, led to increased growth both in the case of rats and chickens. The increase in growth of the chickens varied from 20 to 50 per cent. Robertson, Orr, Prentice, and Macdonald (*Scottish J. of Agric.*, xiii., 410, 1930) found that a supplement of salt (NaCl) was essential for adequate growth and health in chickens fed on a ration of cereals and soya-bean meal. The salt formed 0·44 per cent. of the total ration. The beneficial effect of salt on the growth of the chickens also extended to the egg production, the salt-fed groups laying more eggs than the no-salt groups. In the case of chickens, therefore, on a ration consisting mainly of cereals, the addition of salt to the extent of 0·5 to 1 per cent. of the total ration will in all probability lead to increased growth and egg production. On the other hand, excess of salt will lead to pathological conditions. Collier in 1892 (*N.Y. Agric. Expt. Sta.* (Geneva), *Bull.* 39, N.S., 1982) reported harmful effects on mature hens following the administration of salt. Suffran in 1909 (*Expt. Sta. Rec.*, xxiii., 793, 1910) concluded that 4 grams per kilogram body weight was sufficient to produce death. Mitchell, Card, and Carman (*Ill. Agric. Expt. Sta., Bull.* 279, 1926) found that for birds weighing 3 to 5 lbs. the minimal lethal dose was 4 grams per kilogram body weight, but these authors fed rations to chicks from nine to twenty-one weeks of age on rations containing as high as 8 per cent. of salt without detrimental results. The administration of salt *per se* proved more toxic than similar amounts mixed in the ration.

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Under normal conditions, therefore, mineral or ash ingredients will be included in a ration only in cases where research has shown that the foods fed are deficient in such elements. The amounts fed will depend on the nature of the growth or production, and although care will be taken to avoid feeding amounts large enough to give rise to pathological conditions, the natural excretory functions of the kidneys and skin will be relied upon to remove any excess not required for metabolic purposes.

The Need for " Mineral Ingredients " or " Ash Constituents "—Orr (" Minerals in Pastures," H. K. Lewis and Co., Ltd., London, 1929) points out that wide differences in the amounts of minerals present in different types of pastures exist, and that these differences are associated with (1) differences of flora, (2) stage of growth of the plants, (3) climatic conditions, and (4) nature of the soil. As a consequence, wide areas of land exist the natural herbage of which is deficient in the minerals necessary for animal nutrition. The herds native to such pastures normally maintain their health by periodic migrations to other areas, or by visits to " salt licks," but where domestication has occurred, deficiency diseases due to lack of minerals quickly ensue. Orr classifies the types of pathological conditions according to the nature of the deficiency. Thus " styfsiekte " in South Africa, " coastal disease " in Australia, the " creeps " in Texas, and " Waihi disease " in New Zealand are all due to phosphorus deficiency. Similarly, " nutritional anæmia " is associated with a deficiency of iron, osteoporosis with a deficiency of calcium, and goitre is associated with a lack of iodine.

Even where pathological symptoms do not occur, the minerals may still prove to be the limiting factor in nutrition. The beneficial effect on the growth of animals of the addition of salt to a cereal ration, the increased egg production following the addition of bone meal to a cereal ration, and the improvement of milk yield following the administration of phosphates, all point to the need of considering the mineral or ash content of foods, particularly where heavy production is required.

Iodine—With regard to iodine, the position is by no means clear. That iodine plays an important part in metabolism is shown by the fact that it is an essential constituent of " thyroxin," a crystalline iodine compound obtained from the thyroid glands by Kendall in 1919. Administration of thyroxin produces effects similar to those produced by fresh thyroid. The diseases known as goitre, endemic cretinism, myxœdema, cachexia strumipriva, and Graves's disease, are all associated with a pathological condition of the thyroid gland. The administration of iodides in a diet definitely increases the iodine content of the thyroid, and presumably its effectiveness as an organ of internal secretion. With regard to the effect of thyroid feeding on growth in young animals, inconclusive results have been obtained. Some observers have obtained increased growth, some decreased growth, and others have not noted any difference in growth between the experimental animals and the controls.

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Cameron and Carmichael (*J. Biol. Chem.*, xlv., 69, 1920) in a series of carefully controlled experiments with rats and rabbits, in which experiments the dosage was proportioned to the body weight, found that continued small doses of desiccated thyroid caused a definite decrease in the growth rate, accompanied by a disappearance of fat and an hypertrophy of the organs concerned with increased metabolism. The decrease in rate of growth was proportional to (*a*) the amount of thyroid fed, and (*b*) the iodine content of the thyroid. Sodium iodide fed in quantities varying from amounts of iodine equivalent to the thyroid dosages, to amounts 100 times as great, produced no effect on the growth rate, and no hypertrophy. The work of Marine, Eggenberger, and others (Orr and Leitch, *Med. Res. Council*, Special Rept. Series, No. 123, p. 71) has established the value of iodine as a preventive of goitre. Congenital goitre is definitely prevented by administration of iodized salt to pregnant women, and Stocks finds that iodine treatment is followed by an increased growth in school children. Cameron and Carmichael's work definitely shows that the value of iodine depends entirely upon its effect on the thyroid gland, since iodine *per se* produced none of the effects associated with thyroid feeding. The curative effect of iodine in the prevention of goitre can be attributed to its effect on the thyroid and not to its action *per se*.

The value of iodine feeding will therefore depend upon the metabolic condition of the animal to which it is administered. If the animal is already fully satisfied so far as its iodine requirements are concerned, no beneficial effects will follow its administration. On the other hand, if the iodine is administered in amounts sufficiently large to cause hyperthyroidism, deleterious effects will follow its administration. If the animal is not fully satisfied so far as its metabolic requirements for iodine are concerned—for instance, in an iodine deficient area—then administration of iodine will produce beneficial results and result in improved nutrition. On this hypothesis, the variable and contradictory results obtained by various observers following iodine administration to animals can be explained. E. T. H.

METEOROLOGY AND AGRICULTURE — Weather — *Air, Soil, and Moisture*—All growth is the result of the action and reaction between air and soil, each with its own moisture, under the influence of light and warmth.

Soil is a very composite product, partly mineral, partly vegetable, and partly animal, resulting from the exposure of the débris of weathered rock to the action of air and water.

Air is a mixture consisting mainly of the elementary gases oxygen, the supporter of the chemical action which, in its more exaggerated form, is called combustion, and nitrogen, which takes no part in combustion, and yet is an essential of all animal growth. The mixture is at the rate of four parts of the inert nitrogen to one of the active oxygen.

The next most important constituent of the atmosphere is the vapour of water, the only really variable constituent; at any tempera-

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ture air may be moist or dry in various degrees, according to the amount of water which it carries.

Associated with these is carbonic acid gas, one of the products of combustion of fuel. (See Assimilation and Respiration.) Breathed out by plants and animals, and absorbed by plants, it is found in the atmosphere to the extent of three or four parts in 10,000, and yet on that small amount the life of plants depends, and therefore ultimately the life of animals. There are, besides, small quantities of argon, helium, and other gases which have only been discovered within the last half-century.

Except for the variation of the amount of water vapour the composition of air is the same the world over. Some computations have been made of a special composition where the atmosphere borders on space; it has been said to consist there of the light gases, hydrogen, or helium; or of a still lighter hypothetical gas called coronium, but that is calculation; observation casts the die in favour of a mixture of oxygen and nitrogen with water vapour.

Every living being requires water, and indeed consists largely of water, the product of combustion of hydrogen in oxygen; and water is the medium by which the food of plants and animals is distributed through the body. Hence there is a world of difference so far as plants and animals are concerned between dry air and moist air, dry soil and moist soil. It is the difference between a desert and a land flowing with milk and honey. The first requisite of a habitable world is water; where there is no water everything must perish.

Water Vapour—The study of the importance of water is a part of animal nutrition rather than agricultural meteorology, but a meteorologist cannot omit it. The water in the air comes as vapour by evaporation from the surfaces of water at sea or on land; the water in the soil may come from some underground source, or may be supplied by irrigation from a river; but in the end both these depend upon the rain that falls from the air. So, apart from other characteristics of the atmosphere, the capacity for rain-making is one of primary necessity for the life of plants or animals.

And the exercise of the capacity for rain-making is one of the most thrilling of the processes of nature. Rain is made when water vapour is condensed from the invisible form in which it generally lives in the air into the form of drops. Almost everything about it is surprising. Looking up at the clouds, which are formed of drops too small to fall as rain or snow, they seem to us quite definitely located, sometimes in layers, sometimes in detached masses; and we have to recognize that they are local collections of the droplets formed by condensation. And yet physicists assure us that if it is water we are thinking about there may be more water to the cubic yard in the air just outside our window than in the brightest or the darkest of the clouds in sight. It is no exaggeration to say that all the water in the rain that falls has to be carried up from the surface, and in an invisible form.

Thus, there is a certain romance about water and its vapour which has appealed to many poets; but it is not at all easy to understand

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without some hard thinking. Here is the gist of it. A parcel of air keeps its place in the universe by its pressure; with that it defends itself against its environment. If it lost its pressure it would collapse. We can measure that pressure by the barometer in inches of mercury if we like; but much better in pounds per square inch, or better still in tons per square foot. Those who are familiar with the metric system (*q.v.*) may use grams per square centimetre, and scientific folk use absolute units, dynes per square centimetre; it takes a million of them to balance 29½ ins. of mercury. Ordinarily the pressure of any sample of air at the surface is about a ton per square foot—a kilogram or a million dynes per square centimetre. In maintaining that pressure all the component gases contribute according to their quantity: nitrogen does about four-fifths of the work, oxygen about a fifth, water vapour never more than one-fifteenth and generally less than one-thirtieth, a varying amount to which there is an absolute limit depending on the warmth of the air as indicated by a thermometer.

Here are the limits for the Fahrenheit scale:

Saturation Pressure of Water Vapour in Thousandths of a Ton per Square Foot, and Quantity—in Pounds per Thousand Cubic Yards.

°*F.*	0	32	42	52	62	72	82	92	102
Vapour pressure	1	6	9	12	18	25	35	48	65
Quantity of water	1·7	8	12	17	24	33	45	61	82

The same figures for vapour pressure would not be far wrong for grams per square centimetre, nor for *millibars*, which express thousands of dynes per square centimetre.

This limiting pressure is called the pressure of saturation; and the air which has enough water vapour to give that pressure is "saturated." The weight of water in 1,000 cubic yards of saturated air at the corresponding temperature is given in the third line. If then the temperature rises without any addition to the water vapour the air becomes what is called "dry," because it *could* hold more water; thirsty would be a much better name for it than dry, because dry air has another meaning. If, on the other hand, the temperature of the saturated air falls, its capacity for water is automatically reduced and it has to get rid of its excess; it does that by condensing some of it in drops that float as clouds, or fall as rain if they are big enough.

The cooling of the air to produce rain or cloud is managed by the simple process of reducing its pressure, and the reduction of pressure is brought about by lifting the air to a higher level—another of the surprises of the atmosphere based on facts that make very striking experiments for a lecture-room or laboratory. Air which is forcibly lifted through its environment cools at the rate of approximately 6° of the Fahrenheit thermometer for 1,000 ft., a degree for about 170 ft. It is to that circumstance that the cold of mountain tops is due. As the air is gradually lifted it gets colder until it reaches the saturation point, and further lifting causes the condensation of part of its moisture.

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When the air passes the saturation point, and condensation takes place, the rate of fall of temperature is not so great. One degree for 300 ft. is about the figure for the British Isles. It is different according to the original temperature of the saturated air.

For the ordinary temperatures of the outside air the saturation point is often called the "dew point" (*q.v.*), because dew or hoar frost forms upon any surface exposed to the air if its temperature goes below that point. When the surface gets warmed again by the sun's rays or a warm wind, the condensed water evaporates as vapour and becomes invisible.

In all these operations in the open air we have to take account of the warmth received from the sun and the cooling of the ground at night by the process called radiation.

Radiation would appeal to us as a remarkable mystery if we were not so familiar with it in practice. Anything left exposed to the open, clear sky at night gets colder, and goes on getting colder and colder until it covers itself with dew or frost or fog; and, on the other hand, anything exposed to the sun, or indeed to any body warmer than itself, gets some of the excess warmth of its neighbour if the space between the two is what we call transparent. In a transparent atmosphere every body exchanges radiation with every other body in sight. Questions of transparency of air and glass, and the so-called focussing of the sun's rays by a globe of water or a lens, belong to the science of physics.

And one of the consequences of sunshine and evaporation is wind—what kind of wind, east or west, north or south, depends ultimately upon the rotation of the earth.

For the farmer weather means first of all rain, next warmth, moisture, or dryness; all of these depend on wind, and therefore all on sun and its conditionary circumstances of clear or cloudy sky. For all the events of weather we depend upon radiation, water vapour, and the earth's rotation.

Meteorology—So far weather—meteorology is the study of weather; and the first step in the study of weather is to collect facts about it by careful observation, and to arrange them when they have been noted, so that they shall give us a mental picture of the sequence of events to which we can relate the facts about the behaviour and growth of crops in agriculture, if it is to agriculture that we wish to apply our meteorological knowledge. The same facts may be applied to the conditions of marketing, transport by land or sea or air, also to drainage, to questions of public health, sewage disposal, and all other activities; and indeed few events in life can be said to be independent of the figures which we use for weather.

Naturally, farmers have been doing this kind of meteorology for themselves in their own way since the practice of agriculture began. A farmer who has learned to use a calendar, or to take account of the sun upon which the calendar depends, does not need to be told that generally the day is warmer than the night, or that the air is warmer

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in summer, when the sun at noon is higher and days are longer, than it is in winter, when the sun at noon is lower and the days are shorter. He will hardly think himself a meteorologist because he knows that; nevertheless, it is quite good meteorology based upon quite good observations.

The skilful shepherd has the reputation of being able successfully to predict the weather from the way of the wind or from signs in the sky. That would be quite good meteorology, too, if the shepherd would put down the observations upon which he bases his predictions in an orderly manner, so that the connexion could be definitely verified by others who take an interest in the subject.

Organized meteorology goes some steps farther. It has arranged a scheme of observations which meteorologists think should be useful in answering any questions that farmers may want to ask about the weather. There are two sorts of questions: one sort related to what is called climate, and the other to weather. Climate is the picture which one forms of weather conditions in any locality from a long experience of what has actually happened there in the way of weather; and weather is the sequence of separate events, sunshine or cloud, or rain or snow or hail or thunder, winds or storms, heat or frost.

A knowledge of the climate teaches one what crops will grow, what is the best situation for them or the best seed for a particular field, what is the proper time for ploughing, sowing, gathering, and selling. For an individual farm certain details of climate are important, the site of a plot, its height above sea level, its aspect and exposure to sun or wind. In summer a hill top is cooler than the valley beneath; in winter it is often warmer. These things are the common unwritten knowledge of the farmer who has been brought up on his farm; but when it is a question of migration to a new district, or emigration to a new country, the knowledge of climate that meteorology supplies is really indispensable. To begin farming in a new locality with no more than a practical knowledge of some other district or country is to court disaster.

So far as weather is concerned, distinguished from the summary of weather which we have called climate, knowledge of details is only directly of advantage if we can use it to know beforehand what is coming in the way of weather or of crops. In that department our knowledge is at the best imperfect. By practice a man may learn to interpret the signs that surround him and become weather-wise; but for a knowledge of weather-to-come the accepted plan in these days is to depend more and more on the information collected from a very large area, by wire or wireless, day by day, to form maps in a central government office, and to "listen-in" for the description of future weather which the experts derive from the study of the maps.

The record of the relation of the sequence of weather to crops with their pests and diseases is only now in process of organization.

Meteorological Observations of Weather—The system which meteorologists have organized all over the world in order to express the climate of any locality and to anticipate future weather provides for certain

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observations of the elements of weather, day by day, at fixed hours. The observations are intended to record the state of the air as regards warmth or cold or moisture, and also the variations which have taken place since the last fixed hour, the direction and force of the wind, the state of the sky at time of observing, and a measure of the rain that has fallen in the interval. To these observations, which give an indication of the weather itself, we must add the readings of a barometer as a record of the pressure of the air which, taking the country over, may vary between nine-tenths of a ton and eleven-tenths of a ton per square foot. As a matter of observation the pressure is recorded as the height in inches or millimetres of mercury, at a standard temperature, that will balance it. That method conceals the real meaning of the force which it measures, and the expression of pressure in millibars or thousands of dynes per square centimetre gives more information. The ordinary atmospheric pressure at about 300 ft. above the sea is 1,000 millibars; that gives us a million dynes per square centimetre, and as 980 dynes are the weight of a gram, and there are 930 square centimetres in a square foot, we get the equivalent pressure of the atmosphere on a square foot at about 300 ft. to be the weight of 930/980 million grams, rather more than nine-tenths of an English ton.

The humidity is measured by noting the difference between the temperature shown by an ordinary thermometer and that shown by a thermometer which has its bulb covered with wet muslin. A formula, or in practice a set of tables, is required to give the pressure of the water vapour which, when compared with the saturation pressure, gives the "thirstiness" of the air as the difference between saturation pressure and actual pressure of water vapour.

Instruments—The instruments prescribed by the Meteorological Office, in accordance with international agreement, for use at climatological stations are a mercury barometer for pressure, a dry bulb thermometer, and a maximum and minimum thermometer, in addition, for the temperature of the air; a wet-bulb thermometer to help in the measurement of the humidity of the air for the estimation of its thirstiness; a rain gauge to determine the depth of water equivalent to the rain that has fallen.

The barometer is kept indoors, because in all ordinary circumstances the pressure is the same indoors and out. A mercury barometer is necessary with a proper scale to measure the height of the column of mercury and its temperature, if the readings are to be preserved as records or compared with those in a "weather report." For such official purposes an aneroid barometer may be misleading, because its index is liable in time to get out of step with the pressure; but it can be used for domestic purposes if its reading is compared from time to time with a mercury standard and adjusted to agree therewith. In buying an aneroid barometer care should be taken to get one which shows graduation in millibars, with which millimetres or inches can easily be shown side by side.

With the mercury barometer a proper official reading of pressure is not reached until the length of the mercury column has been "cor-

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rected" for latitude and temperature. The correction is always accomplished by means of tables, which could give the result in millibars just as easily as in true inches.

The expression of pressure in millibars becomes a sort of certificate that the proper corrections have been made, and after a little practice a millibar is not at all incomprehensible. For most of us it is very approximately one-thousandth part of the pressure under which we live.

An observer should always remember that the reading of a barometer depends upon the height of the cistern. It may read a millibar less at the top of the house, 10 metres (33 ft.) high, than at the bottom. For maps, pressures are always reduced to sea level, unless the ground is so high that the reduction would make the reading meaningless.

The thermometers have to be exposed out of doors in an open situation. They have to be enclosed in a louvred wooden screen, so that the bulbs are about 4 ft. above ground. The dry and wet bulbs are read at every visit to the screen; the maximum and minimum morning or evening, sometimes once a day or sometimes twice.

The rain gauge must also be in an open situation with its rim a foot above the ground; it must not be overshadowed by trees or buildings, but a very windy situation is not desirable.

Besides these instruments an agriculturist requires a grass minimum thermometer supported in forked twigs at the grass level and exposed freely to the sky. It is read each morning to tell how cold the bottom layer of air has been in the night; earth thermometers tell the temperature of the soil at 4 in., 8 in., and 2 ft., according to the instructions of the Agricultural Meteorological Committee. The conventional practice in Britain used to be 1 ft. and 4 ft.

A sunshine recorder also generally forms part of the equipment of a climatological station; and if one begins recording there is a very strong temptation to keep a self-recording aneroid barometer for recording pressure, a special instrument for recording temperature continuously, and another for recording solar radiation. If one once becomes accustomed to self-recording instruments, it is difficult to part with them.

The observation of wind is indispensable, but offers great difficulty. A self-recording wind instrument, called an anemograph, is most informing, but it is painfully expensive, and is perhaps worse than useless if it has no suitable exposure. A weather-cock or smoke will tell the direction if the orientation has been properly determined; and the wind force can be estimated on the *Beaufort scale* from the behaviour of smoke or trees. A table of its equivalents in the speed of wind is given on p. 781 for the guidance of those who are unfamiliar with wind measurement.

A wind of force 8 at sea is called a gale, force 9 a strong gale, 10 a whole gale, 11 a storm, and beyond 11 a hurricane.

Clouds can be classified with the aid of a set of typical pictures. The direction and speed of their motion can be observed by the aid of a "nephoscope." At a land station the direction of motion of low

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clouds is generally "veered" (by right-handed turn) through about 45° (half a right angle) from the direction of the weather-cock.

SPECIFICATION OF THE BEAUFORT SCALE WITH PROBABLE EQUIVALENTS OF THE NUMBERS OF THE SCALE.

Beaufort Number.	*Specification of Beaufort Scale for Use on Land, based on Observations made at Land Stations.*	*Equivalent Speed in Miles per Hour* 33 *ft. up*
0	Calm; smoke rises vertically	0
1	Direction of wind shown by smoke drift, but not by wind vanes	2
2	Wind felt on face; leaves rustle; ordinary vane moved by wind	5
3	Leaves and small twigs in constant motion; wind extends light flag	10
4	Raises dust and loose paper; small branches are moved	15
5	Small trees in leaf begin to sway; crested wavelets form on inland waters	21
6	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	27
7	Whole trees in motion; inconvenience felt when walking against wind	35
8	Breaks twigs off trees; generally impedes progress	42
9	Slight structural damage occurs (chimney pots and slates removed)	50
10	Seldom experienced inland; trees uprooted; considerable structural damage occurs ..	59
11	Very rarely experienced; accompanied by widespread damage	68
12	.. ..	above 75

Details about instruments and their use can be found in the official handbooks of the Meteorological Office: "The Observer's Handbook" (5s.); "Instructions to Observers at Normal Climatological Stations" (4d.). Special instructions for agricultural meteorology are given in "Observers' Handbook," published for the Agricultural Section of the Conference of Empire Meteorologists, H.M.S.O., 1929.

Besides the normal meteorological observations it is desirable to add notes on "phenology," which is in practice nature study in relation to the seasons, and includes the migration of birds, the development of insect life, the first flowering of selected plants and trees. Instructions are given in the last-mentioned publication.

Observations of the progress and development of crops and stock, with notes about diseases, pests, or parasites, should follow the report of nature study.

The Meteorological Record of Weather as the Basis of Climate—The professional observers for the Meteorological Office read the

METEOROLOGY AND AGRICULTURE (*Continued*)—

instruments which we have mentioned three times a day: 7 h. (a.m.), 13 h. (1 p.m.), 18 h. (6 p.m.); some of them, where for other reasons night duty is necessary, also at 1 h. (a.m.)—all Greenwich mean time. The observations are made at the same time over the whole of Europe, in order to get a map of the distribution of weather at a single epoch.

At what are called climatological stations worked by observers attached to municipal or agricultural establishments, by gardeners or amateurs, the usual times of observation are 9 h., 15 h. (3 p.m.), and 21 h. (9 p.m.). These times are arranged by international agreement for the purpose of comparing the climates of different countries and different stations in the same country, and for that reason the times of observation are not all intended to be Greenwich time, but *local mean time*, which depends on the longitude of the place of observation; for places 10 degrees of longitude east of Greenwich it is forty minutes *fast* of Greenwich mean time. The line of 10 degrees east runs near to Trondhjem and Oslo in Norway, Copenhagen in Denmark, Hamburg and Hanover in Germany, and Milan and Leghorn in Italy. It is likewise forty minutes *slow* of Greenwich for places 10 degrees of longitude west of Greenwich. That line runs down the extreme west coast of Ireland, and about fifty miles off the west coast of Portugal and Spain. In the British Isles the allowance for local time is not always made. If the international agreement is rigorously observed, an observer at Yarmouth will be at his instruments six minutes before the observer at Greenwich; an observer at Edinburgh or Cardiff ten minutes after the observer at Greenwich; an observer in Skye, or at Dublin or Penzance, about twenty-five minutes after Greenwich; and on the west of Ireland forty minutes. They would all be in the same relation to the sun in its passage across the sky, but not to the railway or post office clocks.

Observations in North America at the same actual time as ours at 7 a.m. would have to be taken at times ranging from 8 p.m. of the day before to 3 a.m. of the same day as reckoned in local time.

The scheme of the Agricultural Meteorological Committee provides a notebook in which an observer can find suitable places for entering his observations three times a day.

Co-ordination of the Observations: The first question that we may ask ourselves is how to use the observations to gain a coherent picture of the weather.

Pursuing the idea of the use of the observations for giving the climate of the locality, the ordinary meteorological practice is to summarize the observations for a month. On p. 783 is a monthly summary for one of the crop-weather stations of the Ministry of Agriculture.

This convention of summarizing the observations according to months was devised by meteorologists before regular observations of the growth and behaviour of crops were taken into consideration, and so climate has come to be regarded as defined or expressed by monthly values. Perhaps a very general idea was sufficient to indicate in what localities crops of a particular kind would flourish. We can provide, for example, a map of the distribution of monthly rainfall over

METEOROLOGY AND AGRICULTURE (*Continued*)—
the world on which one can easily see where there is abundant rain and where there is desert. The "Book of Normals"* of the Meteorological Office gives monthly maps of the distribution of rainfall, sunshine, maximum and minimum temperature for the British Isles, by which it is easy to understand the agricultural differences between east and west, and north and south.

WISBECH, OCTOBER, 1930.

(10 ft. above mean sea level; hours of observation, 9 h., 15 h., 21 h.)

TEMPERATURE IN °F.								RAINFALL IN MM.		
Max.	*Min.*	*Abs. Max.*	*Date.*	*Abs. Min.*	*Date.*	*Accumulated Warmth.* >42° F.	*Accumulated Cold.* <42° F.	*Total.*	*Day's Max.*	*Date.*
58·4	43·4	66	16, 17	29	27	289	17	15		

WEATHER: NUMBER OF DAYS.										SUNSHINE.
Precipitation.										*Daily Mean.*
Water.		*Snow.*	*Snow Lying.*	*Hail.*	*Thunder.*	*Fog.* a.m.	*Ground Frost.*	*Gale.*		
≥0·2	≥1 mm.	*	⊠	▲	T	≡				Hours.
12	5	0	0	0	2	2	5	0		4·37

	SOIL TEMPERATURE.			HUMIDITY, °F. AND PER CENT.			
h.	*2 Ft.* °F.	*4 In.* °F.	*8 In.* °F.	*Dry Bulb.*	*Depn. of Wet Bulb.*	*Dew Point.*	*Relative Humidity.*
9	—	48·3	49·5	50·6	2·2	46·2	85
15	—	54·0	52·4	55·9	4·8	46·3	70
21	—	50·6	51·8	49·1	1·7	45·9	87

WIND: NUMBER OF OBSERVATIONS OF FORCES AND DIRECTIONS.

	Force (0-12).				*Direction.*							
h.	>8	4 to 7	1 to 3	Calm.	N	NE	E	SE	S	SW	W	NW
9	0	14	17	0	0	2	0	2	6	9	7	5
21	0	11	20	0	0	1	1	3	7	11	6	2

But for tracing the progress of growth and the influence of weather on crops something different is required. A very early endeavour to bring meteorological observations into relation with agriculture is to be found in the publication of the *Weekly Weather Report*, which was begun in 1878 after consultation between the directing council of the Meteorological Office of that date and Sir John Lawes and Sir Henry Gilbert, the founders of the experimental agricultural station at Rothamsted.

They wanted something applicable to districts rather than individual stations, and information for periods shorter than a month. They chose the week as their time unit, divided the country up into

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* Meteorological Office Publication 236 (Section III.), 1920, 1s. 6d.

METEOROLOGY AND AGRICULTURE (*Continued*)—

twelve districts, and by taking the average of about ten stations in each district gave the weekly value for rainfall, warmth, and sunshine for each district, as well as for each station. Their idea of warmth was not simply temperature, but "accumulated temperature" above a standard of 42° estimated in day-degrees. Thus, for example, if the temperature was above 42° throughout the day by 3°, the day would count as having contributed 3 day-degrees. A separate account had to be kept for accumulated temperature below 42°, which might be regarded as accumulated cold. A scheme of computation was adopted for broken days when the temperature was above 42° in the day-time and below at night. The totals of accumulated warmth and cold for Wisbech in the month of October, 1930, are included in the table which we have quoted.

The scheme is described in detail in the introduction to any volume of the *Weekly Weather Report* of the Meteorological Office, and an abstract is given in "Manual of Meteorology," vol. ii., p. 49, Cambridge University Press, 1928.

Later on, in order to give the readers of the report a clue to the sequence of weather as well as the summary for the week, the authorities included for each day two small maps of pressure and wind, and one for temperature and weather for the whole of Europe. So a weekly weather report filled six large pages. Temperature, rainfall, and sunshine were given for districts and stations in figures; pressure, wind, and weather for Europe in maps.

The meteorological results derived from these reports have been summarized for the years 1881-1905 to show the normal amounts of accumulated temperature, rainfall, and sunshine week by week for each of the twelve districts of the British Isles. They are represented in diagrams which have been issued by the Ministry of Agriculture, and which show considerable differences in the seasonal occurrence of the elements, particularly of rainfall.

One conclusion which was derived from the information contained in the *Weekly Weather Report* was that copious autumn rainfall was generally followed, and with remarkable proportionality, by a deficiency in the wheat crop, generally of the wheat-producing districts of Great Britain, and especially of Eastern England. This seems to have become the starting point for a definite investigation into the details of the relation between the crops and the sequence of weather upon which they depend. The relation was investigated on statistical methods by R. H. Hooker, and forms the subject of the presidential addresses of the Royal Meteorological Society for 1921 and 1922. The records of Rothamsted have also been investigated by R. A. Fisher ("The Influence of Rainfall on the Yield of Wheat at Rothamsted," *Phil. Trans. Roy. Soc.*, B, 1924, vol. ccxiii., pp. 89-142).

The general question has been put in this form—allowing that warmth, sunshine, and rain are necessary for any crop whatever, what amount of warmth, sunshine, or rain will give the best result for a particular crop, and how should the amounts be distributed through the year?

METEOROLOGY AND AGRICULTURE (*Continued*)—

It is evident that the selection of warmth, sunshine, and rain as meteorological elements is guided by the fact that they are the most easily recorded. Nothing is said in the summaries about wind, which is the hardest of all the elements to measure, and humidity or drying power, which is, for the inexperienced, the most difficult to comprehend.

With that understanding we may pass on to the more recent phases of the inquiry.

Weather and Crops—When we push meteorological investigation beyond the study of the weather itself to the organized study of the relations of weather and crops, something more seems to be required than a weekly summary of the weather at the stations. The final crop does, of course, integrate the result of all the incidents of the weather that have gone to produce it, counting back perhaps to the year before last, or even longer; but nature's method of integrating results is not by taking the means of years or months or weeks or even days. The effect of an inch of rain or a foot of snow may be very different, if it comes in one shower, from what it would be if it came in a week of soft rain or a month of generally fine weather. An inch of rain at one period of the year may do serious damage; at another it may be helpful. The actual circumstances count, not their average values.

When there are three observations a day, one ought to get an idea of the sequence if it can be done without too great sacrifice of space. What seems to me the most informing of the observations, apart from rainfall, is the wind that brings the air over the locality, and the "thirstiness" of the wind as it passes. In order to reduce space to meet the requirements of a typewriter, the writer has in mind that one letter properly chosen is just as effective for wind direction as the collection of letters that sailors use; and, further, from the farming point of view, winds from the east side are essentially different from those from the west. So, with *o* for calm, my wind directions are simply thus:

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
N	NNE	NE	ENE	E	ESE	SE	SSE
S	SSW	SW	WSW	W	WNW	NW	NNW
s	*t*	*u*	*v*	*w*	*x*	*y*	*z*

Giving the force on the Beaufort scale for each of the directions, *a*3 means a north wind force 3, *c*6 a north-easter force 6, and so on.

For the thirstiness of the air one can give the defect of the vapour pressure from saturation in millimetres. It might just as well, or even better, be in millibars if plant physiologists would agree. Meanwhile, it may be remembered that a millibar is three-quarters of a mercury millimetre.

The observations of wind and thirstiness should be supplemented by the highest and lowest readings on the thermometer for the week, as well as by measurements of rain and sunshine.

METEOROLOGY AND AGRICULTURE (*Continued*)—

Specimen tables for Cardington in the Ouse valley, near Bedford, and for Leafield, a moorland plateau in Oxfordshire, are thus:

WEATHER AND CROPS AT CARDINGTON, BEDS. WEEK, NOVEMBER 22 TO 28, 1930.
100 FT. ABOVE SEA LEVEL.

	Sat.	*Sun.*	*Mon.*	*Tues.*	*Wed.*	*Thurs.*	*Fri.*
Min., max. ° F. ..	48 55	37 45	33 54	44 52	38 50	30 41	32 44
Rain (*mm.*), sun (hrs.)	*11* 2	*tr.* 3	*7·1* 0	*1* 4	*2* 3	*1·1* 0	*16* 0
Wind direction ..	*t t u*	*w w u*	*g h v*	*v t u*	*u u t*	*t o c*	*c c b*
Wind force ..	5 6 5	4 4 3	4 6 4	4 5 5	3 4 3	1 0 1	3 5 4
Thirstiness (mm.)	1 3 1	1 3 1	2 0 2	0 2 1	0 3 1	0 0 0	0 0 0
Soil temperature ..							
Phenological observations ..							
Progress of crops ..							
Note on pests and diseases ..							

WEATHER AND CROPS AT LEAFIELD, OXON. WEEK, NOVEMBER 22 TO 28, 1930.
612 FT. ABOVE SEA LEVEL.

	Sat.	*Sun.*	*Mon.*	*Tues.*	*Wed.*	*Thurs.*	*Fri.*
Min., max. °F. ..	46 53	36 45	33 52	44 50	36 47	33 39	29 40
Rain (*mm.*), sun (hrs.)	*8* 2	*tr.* 3	*12* 0	*4* 1	*0·6* 3	*0·2* 1	*14* 0
Wind direction *a* to *h* eastern side; *s* to *z* western side.							
Wind direction ..	*t v u*	*w x s*	*g v t*	*v t v*	*s t t*	*u o z*	*a b b*
Wind force ..	4 6 4	4 5 2	5 5 5	4 5 4	3 4 2	2 0 2	3 4 5
Thirstiness (mm.)	0 0 0	2 2 1	0 2 1	1 1 1	0 2 0	0 0 0	1 0 0
Soil temperature ..							
Phenological observations ..							
Progress of crops							
Note on pests and diseases ..							

The week reported on is in late autumn. There is very little evaporating power at either station, but a little more at Cardington than Leafield.

This suggestion has not yet been tried in practice. It is recommended to those who watch the weather, for their opinion.

The spaces for observations of soil temperature, crops and phenology, pests and diseases, are blank, as those observations are not made at the stations for which daily observations of weather are published.

Meteorology in the Anticipation of Weather—So far we have had in mind the possible or probable influence of weather in the growth of crops as a general guide to agricultural operations. It is more than probable that an experienced farmer will regard the numerical expression of that kind of influence as matter of minor interest, because he knows what is necessary without any reference to tables or maps.

METEOROLOGY AND AGRICULTURE (*Continued*)—

The major interest for him as for the general public is the possibility of anticipating the weather of to-day or to-morrow, or the further future, which the study of weather affords.

The Anticipation of Weather as an International Enterprise—The anticipation of weather has been practised for untold centuries, but the fact that forecasts of weather drawn up by a government office are broadcast several times a day puts the question upon a new basis. Let us first consider how that is done.

The most obvious difference between modern forecasting and the practice of the weather-wise shepherd is that it is done by maps based on information supplied by telegraph—the information is of the same kind as that used for a record of weather and climate, but the method of using it is quite different. According to our own practice—at a certain hour fixed by international agreement—forty-six observers in the British Isles, ninety in the European continent and islands, and about twelve on ships at sea, within range, go to their instruments and make their observations, and report by wire or wireless to the headquarters of their respective countries. The information is broadcast in code by the respective headquarters. Within an hour all the meteorological offices of Europe have got before their forecasters a map of the distribution over Europe of pressure, change of pressure in the previous three hours, wind, temperature, humidity and weather, which includes visibility, the state of the ground and of the sky, the form and movement of clouds, as well as the condition as regards rain, snow, or other accidents.

On the maps are drawn lines connecting stations where the pressure is the same—isobars. Besides the map for the immediate neighbourhood, a map of practically the whole northern hemisphere is compiled by using observations not strictly simultaneous as a guide to the general condition.

The essential feature of forecasting by maps is that weather is regarded as travelling, generally from west to east, but with various divergences. By the study of successive maps a forecaster can form an opinion as to the result of the travel of the weather during the ensuing twenty-four hours. Farther than that the laws of travel are not sufficiently well developed; and long experience is necessary to interpret such signs as there are.

What exactly travels when we say that weather can be predicted from the travel on a map is not finally decided. From the first analysis of the examination of weather maps in 1879 to the end of the war, it was the distribution represented by isobars that was regarded as travelling. The shapes of isobars were classified into cyclonic depressions, formed by closed curves surrounding a centre of low pressure, and anticyclones, also closed curves but surrounding centres of high pressure. Various other types are also identified on maps as secondary depression, V-shaped depression, wedge or ridge of high pressure, and col—the saddle at the junction of two high pressures alternating with the two low. These can easily be identified on a weather map, and in a succession of maps the general idea of travel is easily traced.

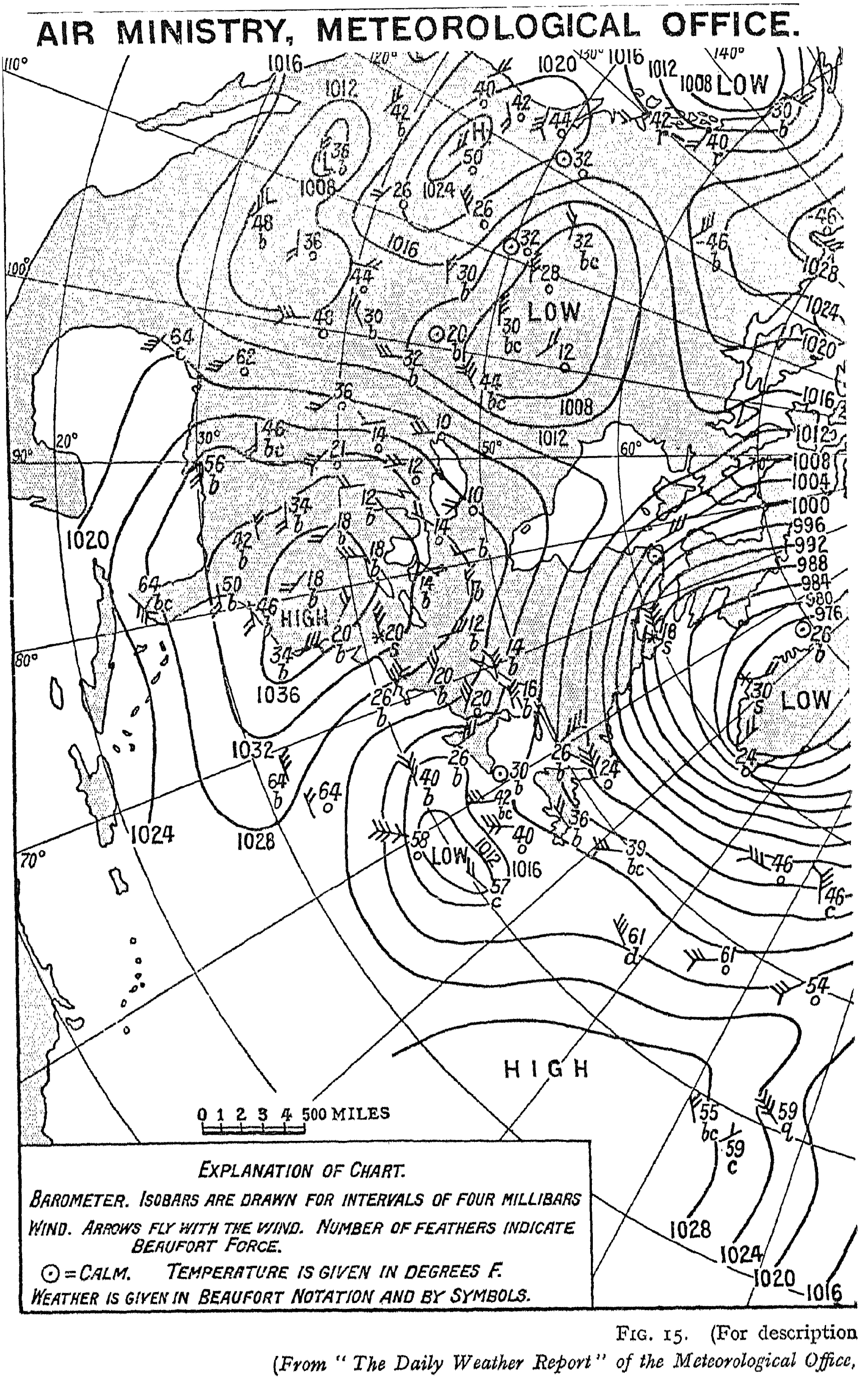
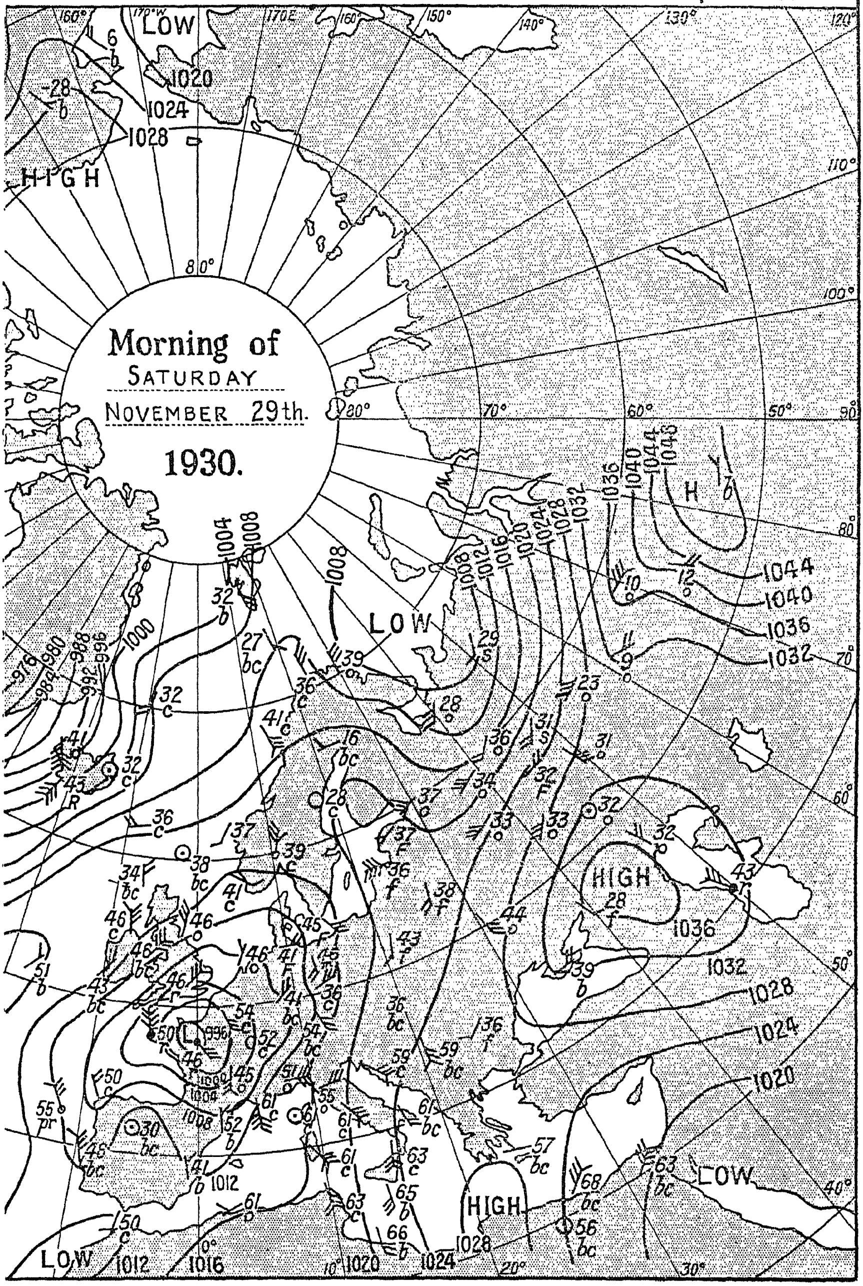

AIR MINISTRY, METEOROLOGICAL OFFICE.
LOW
LOW
LOW
LOW
HIGH
HIGH
H
L
1036
1032
1028
1024
1020
1016
1012
1008
1004
1000
996
992
988
984
980
976
0 1 2 3 4 500 MILES
EXPLANATION OF CHART.
BAROMETER. ISOBARS ARE DRAWN FOR INTERVALS OF FOUR MILLIBARS
WIND. ARROWS FLY WITH THE WIND. NUMBER OF FEATHERS INDICATE BEAUFORT FORCE.
⊙ = CALM. TEMPERATURE IS GIVEN IN DEGREES F.
WEATHER IS GIVEN IN BEAUFORT NOTATION AND BY SYMBOLS.

FIG. 15. (For description

(*From "The Daily Weather Report" of the Meteorological Office,*

Chart of Weather in the Northern Hemisphere.



see p. 790.)

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London, by permission of the Controller of H.M. Stationery Office.)

METEOROLOGY AND AGRICULTURE (*Continued*)—

To the distribution of pressure the winds can be related by the development of what is known as Buys Ballot's Law, that the wind as it advances keeps lower pressure on its left (in the northern hemisphere) and higher pressure on its right; and the strength of the wind is indicated by the closeness of the isobars which give the general idea of its direction. It is understood that, for certain obvious causes, these relations of wind and pressure are imperfectly indicated in the surface-winds recorded on anemometers. Better agreement is found in the upper air.

The exposition of the method of forecasting by means of weather maps requires a good deal of space and ample illustration. It was set out briefly for the use of airmen and others during the war in a little book of some forty 16mo pages, which was called "The Weather Map." Quite recently, in continuation of the same purpose, the work has been re-written officially and expanded into a book of some eighty 8vo pages, which explains a new method of describing the travel of weather introduced into general meteorological practice since the end of the war by the Norwegian school of meteorologists. According to this new method, a cyclonic depression or any other distribution of pressure is made up of moving masses of air currents derived from different sources and reacting one upon the other in the region covered by a cyclonic depression. Two types are conspicuous: a warm and moist current of equatorial air flowing from the south or south-west and impinging upon a current of cold, dry polar air which crosses the warm front of the equatorial air. In its turn the front of a current of polar air impinges upon the flank of the equatorial air and advances beneath it.

From circumstances of which this is a brief indication, a doctrine of the advance of warm and cold fronts is evolved so that the travel which the modern forecaster keeps in mind is not so much that of the centres or ridges of low or high pressure as that of the fronts of the

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On the map, Fig. 15, pages 788 and 789, land-areas are shaded, sea-areas are left blank except for lines of latitude and longitude and weather-information. The centre of the circle enclosing the date of the map (Saturday, November 29, 1930) is the north pole of the earth. It is in ice-covered sea; the shaded area on the right is the Siberian coast, on the left the north coast of Greenland and the islands North of America famous in the annals of polar exploration. Above the centre is the Behring Strait between Asia and America, below it the North Atlantic Ocean, the British Isles, Europe and a bit of Africa. The circle itself shows latitude 80°, other circles 70°, 60°, 50°, 40°, and 30°.

The position of a statio n is indcated by the point of an arrow; the line of the arrow leading to the station shows the direction of the wind, north being always that which leads *from the pole*; the number of feathers shows the force of the wind on the Beaufort scale (p. 781). Close to the station arrow is a number; that is the temperature on the Fahrenheit thermometer; under the number is a letter indicating weather at the time of observation in the Beaufort notation, *b* blue sky, *bc* sky partly cloudy, *c* generally cloudy, *d* drizzle, *f* fog, *F* thick fog, *o* overcast, *q* squalls, *r* rain, *s* snow. Rain is also shown by a black spot at the station, snow by a star (*).

Pressure in millibars is shown by thick lines representing isobars, *i.e.*, lines along which pressure (at sea-level) is the same—each line is labelled with its pressure. Regions of *cyclonic depression* are marked LOW or L. They lie over the Red Sea, centred near Paris, on the steamer-route of the Atlantic, the North Pacific, the desert region of North America, Northern Canada, and most notably over Greenland. Regions of high pressure, anticyclones, are marked HIGH or H.

METEOROLOGY AND AGRICULTURE (*Continued*)—

advancing currents of polar or equatorial air, of which the pressure system is composed.

This view of what travels deals quite definitely with the surface air, and is not much concerned with the reflection that the winds, as recorded on an anemometer, are much more unruly than the currents in the air above.

In any case, forecasting by weather maps requires weather maps for its exposition, and without an adequate series of them discussion has no point. So with these general remarks we may refer the reader to "The Weather Map" for instruction in the art of forecasting.

Long Range Forecasting—Very many efforts have been made to extend the range of forecasts from the day to the season, and predict the course of the weather for a long period ahead. The methods employed include the recognition, from long records, of periodic recurrence of warm or cold, rainy or droughty seasons, and the numerical relations between present and past weather which are disclosed by the computation and examination of coefficients of correlation between the records.

This last method has been adopted as a national or imperial enterprise in British India and Dutch East Indies, but not yet, so far as we know, elsewhere. The literature of the subject is very voluminous, and is referred to in "Manual of Meteorology," vol. ii., pp. 320-33, 338.

The Anticipation of Weather as a Local Enterprise—We have explained that the use of simultaneous meteorological data in the compilation of weather maps and the inferences to be drawn from them about to-morrow's weather for any locality can only be practised satisfactorily if maps are regularly drawn and studied. From this point of view the application of the broadcast inferences would be much enhanced if the listeners had before them a copy of the maps on which the inferences are based, and could trace the unfolding of the anticipated new situation from the old.

With suitable wireless equipment, that is really possible for anyone who chooses to undertake it. The data are broadcast in code, and can be taken by any recipient with suitable apparatus. For a single individual the collection of the data and the preparation of a map would require too much time and effort, but it is quite within the range of good practice for someone at a village school to collect the information and map it for the local community.

In that way the technical terms which forecasters use would be commonly understood, and the whole scheme of the distribution of weather information would be greatly advanced.

The codes and decodes used in the transmission are set out in "Instructions for Meteorological Telegraphy," M.O. publication 191/1, 2nd edit., 2s. 6d. net. Particulars of the messages sent out from the various centres are given in M.O. 252 (7th edit.), "Particulars of Meteorological Reports issued by Wireless Telegraphy in Great Britain and the Countries of Europe and North Africa," 1929, 5s. net. The modifications in the arrangements made are set out in twenty-two supplements issued since the publication of the "Particulars."

METEOROLOGY AND AGRICULTURE *(Continued)*—

The Anticipation of Weather as an Individual Enterprise—To come back, then, to the position taken up before the invention of the weather map, when information was confined to what could be obtained on the spot:—

From the point of view of anticipating, the barometer was regarded as the most important of all the meteorological instruments, partly, it may be confessed, because it was compact and easy to read. The wind would certainly have come into competition with it if it were as easy to get a good wind reading as it is to get a barometer reading, and to-day, perhaps, already thermometer readings are regarded as even more important than barometer readings.

The first effort to use the barometer as a "weather glass" is to be found in the legends—"stormy," "much rain," "rain," "change," "fair," "set fair," "very dry"—on the dial of the wheel barometer introduced by Robert Hooke soon after the invention of the mercury barometer, and now to be found all over the world on aneroids as well as mercury barometers.

There is really little justification for the legends; and, at any rate, they ought not to appear at the same points of the dial for barometers to be used at different heights above sea level. In the country round Buxton, for example, which is about 1,000 ft. above the sea, the barometer will always read about an inch lower than one in the near neighbourhood at sea level; and thus would indicate "rain" when its neighbour showed "fair." The actual legends are most appropriate for a place about 300 ft. above sea level, and were probably set out originally for somewhere near London.

But in any case the weather does not correspond in any rigid sense with the actual height of the mercury. It is generally stormy if the barometer is down to 28 in., but not always very dry when it is up to 31. What one can infer from the barometer is that where it is very low, below 29 ins., changes are likely to be rapid, and where it is up above 30, changes are likely to be slow. We may have a patch of brilliant weather with a very low barometer, but only for a short time; on the other hand, weather may be dull with the barometer at 31, but it is not likely to change rapidly.

Anyone who possesses a self-recording barograph will find increasing interest in relating the rainfall to the trace. The barometer is generally falling when it rains; but in thundery or squally weather a sudden rise of the barometer, which occurs not infrequently in the course of a long drop, may be accompanied by a heavy shower.

Admiral FitzRoy, the head of the original Meteorological Department of the Board of Trade, put a number of prognostics to be drawn in a "Barometer Manual"; but it is for sailors rather than for agriculturists.

More than a century ago a set of rules for anticipating weather were set out by the "Shepherd of Banbury." As tested by recorded experience since the beginning of the present century they are not exactly satisfactory.

The most hopeful way is to obtain a general idea of the situation

METEOROLOGY AND AGRICULTURE (*Continued*)—
from the broadcast inference, and watch the sky and keep an eye on the barometer and wind to see whether the anticipated changes are in progress or not.

The Control of Weather—From the point of view of physical processes, weather is controlled by solar and terrestrial radiation, by the behaviour of water in its different forms, by the rotation of the earth, and by the distribution of land and sea. The agency by which the air is coerced into moving its quarters is the alteration of what is technically called its potential temperature or entropy. The study of the actual process belongs to dynamics on the one side and thermodynamics on the other

None of these things comes within human control. On the natural scale the quantities involved are enormous. To make a large cyclone the effort would be the same as lifting all the water from the Irish Sea and dumping it on the surrounding shores, and the smallest effort that we have been able to measure, hardly noticeable in the records, disclosed the excavation of twenty-five thousand million tons of air. Nevertheless, suggestions have been made for the use of the modern developments of electricity or of explosives to obtain the local control of weather in the interest especially of agriculture.

For dwellers in the most favoured parts of the earth, it may seem remarkable that it is generally the making of rain which is aimed at; but that is probably instinctive.

In any case the suggestions have not commended themselves to the meteorologists responsible for the national services, and probably for many generations yet to come it will be left to private enterprise.

N. S.

METRIC SYSTEM—Every scientific system of measurement is founded upon certain fundamental units, the remaining units being founded upon these. It is to a certain extent immaterial which units are selected as fundamental, but the system tends to be simpler the more easily comprehensible the fundamental units are with reference to the fundamental concepts of the human mind known as space, matter, and time; *e.g.*, engineers frequently use a system known as the gravitational system, in which the fundamental units are those of length, force, and time, but for some reason this seems less natural to the untrained mind, probably because the relation of force to matter is psychologically less close than that of mass. Thus, in all systems which have grown up naturally, through long ages, there is a tendency to found all other ideas on those of length, mass, and time, and when this is carried to its logical conclusion we have an *absolute* system in which all other magnitudes are measured in terms of these three. Given this much, the systems may yet differ in the units of length, mass, and time chosen, and in electrical science, in which a fourth fundamental is introduced—for example, the dielectric constant—they may even differ in the form of the defining equation, as in the system of Heaviside. An absolute system of this type, based upon the number *ten* as a universal scale of

METRIC SYSTEM (*Continued*)—

notation, is known as the *Metric System*. Introduced by the *Loi du 18 Germinal, an* iii. (April 7, 1795), it is one of few prized heritages of humanity provided by the French Revolution. In the metric system the units selected are: for length, the *metre*; for mass, the *kilogram*; and for time, the *mean solar second.*

The *Metre* is defined as the distance, measured at a temperature of 0° C., between the ends of a platinum rod constructed by Borda and kept at Paris.

The *Kilogram* is the mass of a piece of platinum kept at Paris, and known as the " Kilogramme des Archives."

The *Mean Solar Second* is one 86,400th part of the time which elapses between one transit of the mean sun across the meridian and the next.

The metric system is now obligatory in most European countries, and is legal in the British Empire, America, Russia, Turkey, and Japan.

It may be noted that the metre was originally constructed to be one 10,000,000th part of the polar quadrant of the earth, and the kilogram to be the mass of one cubic decimetre of water at 4° C., but in neither case was the measurement correct, so that the definition must be in terms of the actual material standards if the fundamental and all derived units are not to change with every more accurate determination. In the case of time this drawback is clearly unavoidable, but luckily it is a unit which can be fixed with very great accuracy.*

In scientific laboratories it is usual to use submultiples of the metre and kilogram for most purposes—namely, the centimetre ($=\frac{1}{100}$ metre) and the gram ($=\frac{1}{1000}$ kilogram). In general, submultiples of the metre, the gram, and other units are indicated by Latin prefixes as follows:

deci- $=\frac{1}{10}$ unit
centi- $=\frac{1}{100}$ unit
milli- $=\frac{1}{1000}$ unit

while the multiples are indicated by prefixes derived from Greek as follows:

Deka- = 10 × unit
Hecto- = 100 × unit
Kilo- = 1,000 × unit

and for these capital letters are usually employed.

For many scientific purposes units of length and mass, both less and greater than those indicated by the prefixes, are required, and this is usually achieved by making use of indices thus: 31,000,000 grams is written $3{\cdot}1 \times 10^{7}$ gms., 0·0000472 cms. is written $4{\cdot}72 \times 10^{-5}$ cms. In microscopy a unit equal to $\frac{1}{1000}$ of a millimetre is called one *micron* and written 1 μ, while for some purposes a 1,000th part of this again is used under the name of one *micromillimetre* ($=1\ \mu\mu$), and even a 10th of this, known as a *tenth-metre* (sic) or Ångström unit.

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* Since the metric system became international, an International Bureau of Standards has been established at Paris, and reference in international matters is to the copies of the standards there preserved.

METRIC SYSTEM (*Continued*)—

Square and cubic measures in the metric system need no special mention; they are squares and cubes of their linear equivalents.

Capacity is measured in *litres*, one litre being the capacity of a cubical box each side of which is one decimetre in length.

Angles are still universally measured in degrees, minutes, and seconds in metric countries, although a metric system of measurement (grades, etc.) does exist; for scientific purposes circular measure of angles (radians), based on length, but of zero dimensions in this, is often employed.

A few other metric derived units are perhaps worthy of mention here, namely:

Speed—1 cm. per second.

Acceleration—1 cm. per second per second.

Force—That required to impart unit acceleration to a mass of one gram; this is named the *Dyne*.

Work—That done in moving one centimetre against a resistance of a dyne; this is named the *Erg*.

For definitions of other physical magnitudes and units in the metric system, reference may be made to any set of physical tables, *e.g.*, the Smithsonian Physical Tables; Landolt and Börnstein, " Physikalische Tabellen "; or the International Critical Tables.

It remains only to append a list of British weights and measures in common use in various fields of agricultural science with their metric equivalents:

CONVERSION TABLE.

British to Metric.	*Metric to British.*
*1 inch = 2·539998 centimetres.	1 centimetre = 0·3937011 inch.
*1 yard = 0·9143992 metre.	1 metre = 1·09361 yards.
1 mile = 1·60934 kilometres.	1 kilometre = 0·62137 mile.
*1 square inch = 6·4515898 square centimetres.	1 square centimetre = 0·15500 square inch.
*1 square yard = 0·8361259 square metre.	1 square metre = 1·19599 square yards.
*1 acre = 0·4046849 hectare (10,000 square metres).	1 hectare = 2·4711 acres.
*1 cubic inch = 16·3870253 cubic centimetres.	1 cubic centimetre = 0·0610239 cubic inch.
*1 cubic yard = 0·76455285 cubic metre.	1 cubic metre = 1·30795 cubic yards.
1 fluid drachm = 3·55153 cubic centimetres.	1 cubic centimetre = 0·28157 fluid drachm.
1 gallon = 4·54596 litres.	1 litre = 0·219975 gallon.
1 grain = 64·79892 milligrams.	1 milligram = 0·01543 grain.
1 ounce = 28·34953 grams.	1 gram = 0·0352739 ounce.
1 pound = 0·45359 kilogram.	1 kilogram = 2·20462 pounds.
1 hundredweight = 0·50802 quintal (100 kilograms).	1 quintal = 1·96841 hundredweights.
1 ton = 1·01605 tonnes.	1 tonne = 0·9842 ton.

In approximate computations it is, of course, unnecessary to take all the significant figures shown above into account; *e.g.*, one may reckon 30½ centimetres to the foot, 2·2 pounds to the kilogram, etc.

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* Legal conversion factors, remainder from Smithsonian Physical Tables.

MICE—See Rats and Mice.

MILK—Milk is a physiological liquid, and although much has yet to be learned of the physiology of lactation, there is now a tendency for research work to give this fact greater recognition than in the past. (See Milk Secretion and Milking, under Dairying.)

Milk, perfected by natural selection, may be regarded as the link which joins succeeding generations of mammals, providing a diet adjusted to the requirements of the young of the particular species.

The milks of the different mammals have much in common, and consist of more or less opaque and white fluids which, on passing into the stomach of the suckling young, are converted into a curd, or in some cases a flocculent precipitate. All contain somewhat similar groups of components.

Although cows' milk is by far the most important from a commercial point of view, increasing recognition is being given to the milk of the goat, and a revival of interest in the milk of the ewe seems probable.

Comparison of the proximate analysis of the milks of different animals with that of human milk (see Table I.) indicates the direction in which alterations in composition may be effected in the production of humanized milk. In the case of cows' milk the alteration is effected by reducing the proteins and ash by dilution, and restoring the fat by the addition of cream. In a recent development it is suggested that the upper portion of a bottle of milk after standing should be diluted and adjusted to the composition of human milk by adding lactose.

TABLE I.

Proximate Composition of Milk of Different Mammals.

	Cow.	*Goat.*	*Ewe.*	*Human.*	*Ass.*	*Mare.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Water	87·27	84·14	81·90	87·41	89·88	90·68
Fat	3·66	6·00	6·52	3·76	1·50	1·17
Casein	2·95	3·04	4·57	0·91	0·73	1·27
Albumin	0·52	0·99	1·26	1·23	1·31	0·75
Lactose	4·91	5·02	4·82	6·29	6·09	5·77
Ash	0·69	0·81	0·93	0·31	0·49	0·36

Reference.—Rogers, "Fundamentals of Dairy Science," American Chemical Society Monograph 41, p. 17.

That artificial selection has altered the milk of the cow is apparent from Table II. (J. F. Tocher, "The Causes of the Variation of Butter-Fat in Milk," *Scott. J. Agric.*, vol. x., January, 1927), which gives the percentages of fat in the milk of different breeds of cows.

The remainder of this article will deal with the milk of the cow, first as a whole, and afterwards as to its constituents, variation in composition, and with processed cows' milk.

Cows' milk varies in colour from almost white under some systems of winter feeding to a golden-yellow colour with grass feeding. This

MILK *Continued*)—

alteration in colour is due to carotin derived from green foods or carrots.

TABLE II.

AVERAGE FAT IN THE MILK OF COWS OF DIFFERENT BREEDS.

	Per Cent.
Jersey	5·43
Guernsey	5·16
Kerry	4·67
Welsh	4·40
Ayrshire	4·09
Shorthorns	3·91
British Friesians	3·63

The colour of milk is not necessarily a measure of its richness, although the two are associated in the public mind. It appears that more consideration should be given to the preference for coloured milk, and the inclusion of kale, etc., in the winter diet makes this possible (Golding, Soames, and Zilva, *Biochem. J.*, vol. xx., No. 6, pp. 1306-1319, 1926).

Normal milk as it leaves the udder has a slightly acid reaction (pH 6·6). Cows which are nearly dry, and quarters affected with mastitis or similar bacterial invasions of the udder, give alkaline milk. Early trouble in any quarter can be detected by drawing a little of the milk on to yellow strips of ash-free filter paper, previously impregnated in a solution of brom-cresol purple, and afterwards dried (Golding, *J.R.A.S.E.*, lxxxi., p. 68, *ibid.*, lxxxii., p. 205). Normal milk gives a greenish or pale purple colour on such test papers, easily distinguishable from the deep purple colour given by alkaline milk having a pH of about 7 and upwards.

The test has proved of value in detecting udder troubles at an early stage. Stableforth has recently investigated this reaction in relation to disease (A. W. Stableforth, " Studies on Bovine Mastitis," *J. Comparative Pathology and Therapeutics*, vol. xliii., pp. 22-30, March, 1930).

Fresh milk has a titratable acidity due to the presence of acid salts which is usually expressed as its equivalent of lactic acid 0·14 to 0·2 per cent., although no lactic acid is present.

A physiological condition of fresh milk dependent on the constant osmotic pressure of the cow's blood (Winter, *J. Arch. de physiol.*, viii., 114, 1896) is the freezing point, which remains very constant at about −0·55° C., despite variations in the composition of the milk. In Australia, New Zealand, Holland, and the United States of America, this determination constitutes an official method by which watering is detected. Fresh market milk is said (R. L. Andrew, *The Analyst*, vol. liv., p. 216, 1929) never to be nearer to zero than −0·53, −0·52 indicating an addition of 5 per cent. added water. With abnormal but unadulterated fresh milks the freezing point is normal.

The maintenance of a constant osmotic pressure, as shown by the freezing point with different percentages of solids in solution, involves

MILK (*Continued*)—
a natural adjustment of soluble constituents in the milk, since, as the lactose falls, the ionized salts (chlorides, etc.) increase.

The other constituents of milk form a complicated colloidal system composed of several phases varying in their degree of dispersion. The fat globules are 0·1 μ to 10 μ in diameter, but milk is still fairly opaque when these are removed.

From a chemical point of view, many of the components of milk are combined, but they may be classified into groups as follows:

Proteins (casein, albumin, globulin, etc.).
Fats (see Butter), carbohydrates (lactose).
Acids (citric, phosphoric, chlorine).
Bases (potash, soda, lime, magnesia).
Traces of iron, copper, zinc, iodine.
Vitamins (A, B_1 and B_2, C, D).
Enzymes (peroxidase, reductase, lipase).

For analytical purposes the milk is divided into fat and solids-not-fat. The proteins, sugar, and ash are not always determined.

The Sale of Milk Regulations, 1901, provide that a sample of milk that contains less than 3 per cent. of fat or less than 8·5 per cent. of other solids is to be presumed . . . not to be genuine until the contrary is proved. (See Milk, Provisions relating to the Production and Sale of.) Although the average composition (see above) is well above these limits, milk varies in composition, and samples of genuine milk, not only from individual cows (J. F. Tocher, "Variations in the Composition of Milk," H.M. Stationery Office, 1925), but also from mixed milk, have been shown to fall below the standard required by law.

The subject of "Variations in the Composition of Milk" has been summarized in the Ministry of Agriculture's Miscellaneous Publication, No. 65, and has been the subject of investigation by Cranfield (*J. Agric. Sci.*, vol. xvii., part i., January, 1927) and other workers.

Mackintosh has discussed "Circumstances influencing the Yield and Quality of Milk" (*Trans. High. and Agric. Soc. Scotland*, 1925).

The quantity of milk may be greatly affected by feeding, but the percentage of the fat remains much the same with high or low feeding, nor can the percentage of solids-not-fat be altered at will.

Much attention has been given to this subject in recent years, but the causes and remedy for low non-fatty-solids still remain obscure.

In the case of the fat, the hours of milking have a considerable influence, and where a short day interval is followed by a long night interval, the morning's milk will be considerably lower in fat percentage than the evening's milk, though it does not follow that the intervals of time are responsible for the difference.

Collins discusses the problem in a paper entitled "Variations in the Amount of Fat in Milk due to Variations in the Times of Milking" (*Proc. of Univ. of Durham Phil. Soc.*, vol. iv., No. 1, part 1, p. 35).

MILK (*Continued*)—

The difference in the percentage of fat in the milk of different breeds of cattle (see above), provides a method of adjusting the bulk milk in practice.

The fat in milk is readily determined by the Gerber method. Butyrometers, which can now be procured with the National Physical Laboratory stamp guaranteeing accuracy of graduation, are spun for three minutes in a special centrifuge. The butyrometers are first filled consecutively with 10 c.c. sulphuric acid (sp. gr. 1·825), 1 c.c. amyl alcohol, and 11 c.c. of milk, also from a standard pipette. The liquids are rapidly mixed after the butyrometer has been closed with a rubber cork. After spinning in the centrifuge for three minutes at 1,000 revolutions per minute, the volume of fat can be read off on the graduated neck of the butyrometer; the error with standardized glassware is not greater than ±0·05 per cent. of fat. The density of the milk is taken with a special lactometer. From these two determinations an approximation of the total solids can be calculated. The only advantage of this approximate calculation over the method of evaporation and weighing the total solids is the saving in time, and this at the expense of accuracy.

Processed Milks—Although it is now possible to get milk in the raw state which is so free from contamination that it will keep fresh for a much longer time than formerly, and although in the cases of certified and Grade A (T.T.) milks the possibility of contamination from bovine tubercle bacillus is guarded against, nevertheless the bulk of milk in large cities has to be " processed " to attain the same object. The method which produces least apparent change in the milk is pasteurization, which consists in heating the milk to a temperature of 145° F., and holding it at this temperature for thirty minutes before cooling and bottling. At this temperature, as Dr. E. C. V. Mattick has shown (*J. Agric. Sci.*, vol. xix., part iii., pp. 452-462) apparent changes take place in the action of rennet on the milk and in the percentage of diffusible calcium. Nutritional experiments have also indicated differences in favour of the unpasteurized milk when the two types are fed to infants.

At higher temperatures greater changes can be demonstrated, and the taste is more definitely altered. The peroxidase is destroyed, and the albumin is rendered insoluble.

It is on account of these changes that " flash " pasteurization, in which the milk is heated to 168° F. or to 180° F. and then rapidly cooled, has been replaced for the whole milk trade by the " holder " process mentioned above.

In sterilization milk is generally heated for half an hour to 212° F. in bottles which are then closed while full of steam. Complete sterilization does not take place, but the destruction of the great majority of the bacterial flora and the exclusion of air confer prolonged keeping qualities on this milk.

The chemical changes are, however, still more pronounced, and the " sterilized " milk has a distinctive flavour.

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The reader is referred to the following articles for other aspects of the subject: Milk and Milk Products, Bacteriology of; Milk, Provisions relating to the Production and Sale of; Milk, Recent Improvement in the Production and Distribution of. J. G.

MILK AND MILK PRODUCTS, BACTERIOLOGY OF—In practically all civilized countries, particularly in England and America, the present century has witnessed an increasing interest in the milk supply from the bacteriological standpoint.

It is becoming more and more evident that the modern demand for high-class dairy produce can only be met by improvements in the primary product itself. Improvements in the methods of milk production at the farm are bound to be reflected in the general farming practice, since these involve attention to detail hitherto considered unnecessary (Mattick, "Production and Distribution of Clean Milk," London, 1927).

The importance of a clean milk supply for all purposes has been recognized by the establishment of a Dairy Bacteriologist in each English province served by the Agricultural Colleges and University Faculties of Agriculture. Clean milk competitions in nearly all the dairying counties in England have quickly led to marked improvements in the milk supply ("Guide to the Conduct of Clean Milk Competitions," *Min. Agric. Fish.*, Misc. Pub., 43, 1928).

The efforts made to avoid contamination of milk after it leaves the udder, and to supply milk which does not sour or otherwise spoil as the results of bacterial action, has redirected attention to the flora of the milk before it leaves the udder. In America, where in many places a maximum of 10,000 organisms per 1 c.c. only is allowed, it is likely that the extent of this initial flora may have practical importance, although in England, where the most severe standard is 30,000 per 1 c.c., it is only in exceptional cases that it would cause difficulty, especially when the fore milk, which contains a high percentage of the total udder bacteria, is rejected. The udder bacteria consist, in the normal healthy animal, of micrococci or rods, whose action on milk is normally slow and not of great practical significance from the point of view of keeping quality. Moreover, most of them fail to grow on standard agar plates, so that it is only exceptionally that the udder flora will seriously affect the plate count of milk. It is of interest to note that the organisms which predominate in the udder flora are different in different countries (Dorner, *N.Y. Agric. Expt. Stat. Tech. Bull. No.* 165, 1930).

In addition to the innocuous organisms which are always present in greater or lesser numbers in the udder, others of importance are sometimes found. Many apparently healthy udders harbour a number of streptococci which, whilst quite harmless to human beings (Savage, *Vet. J.*, lxxvii., 158, 1921), may, under suitable conditions, be pathogenic for cows. A percentage of the healthy udders of cows which have aborted may contain *B. abortus* and similar organisms. The former is of some importance, since it has a definite but low pathogenicity for

MILK AND MILK PRODUCTS, BACTERIOLOGY OF (*Continued*)—
man, and has been held to be the cause of irregular fevers in man (Evans, *J. Inf. Dis.*, xxii., 576-579; xxiii., 354-372, 1918).

In general, it is true to say that the variety of types of bacteria found in the healthy udder is small, and that by far the greater part of the flora of ordinary market milk results from contamination after the milk has left the udder.

The commonest milk organism, which is responsible for typical souring (*Streptococcus lactis*), is not found in the udder itself, but can be recovered from the saliva, skin and hair of the cow, and the dung. It is always present in large numbers in old milk and milk residues. For this reason improperly sterilized utensils are sources of gross contamination of milk. Coliform organisms, which are very common contaminants of milk, are also not found normally in the udder. Their presence in milk was at one time taken as evidence of fæcal contamination, but they are now known to be almost ubiquitous. Nevertheless, since the presumptive estimation of these organisms in milk is easy, and since they do not occur in the udder, their presence has been successfully used as an index of the care taken in the production and handling of the milk. For example, it is required that certified milk (produced under licence of the Ministry of Health) shall not contain *B. coli* in $\frac{1}{10}$ c.c. (See Milk, Provisions relating to the Production and Sale of.)

The increasing interest in milk hygiene displayed by the Public Health and Sanitary Authorities has directed attention to the methods in use for determining the numbers of bacteria present. The methods include the plate count, Frost's little plate method, Burri's smear method, Breed's and Skar's direct microscopic methods, and the Reductase test.

Of these the plate count is most generally used, and gives the most accurate idea of numbers. It is admittedly subject to errors, some of which appear to be insurmountable. Such things as clumping of bacteria, the varying nutritional and temperature requirements, and difficulties of sampling, cause errors which are not constant for all samples. It should, therefore, be clearly recognized that most figures of bacterial numbers in milk are in some measure fictitious. Fortunately, this does not detract from the great practical value of the test when interpreted with full knowledge of its deficiencies. By its use milk can be accurately separated into broad grades. Experience has shown that certain deductions as to the value of milk may, in general, safely be made on the evidence of the plate count, and it is found that plate count and keeping quality can be correlated, especially when the numbers of coliform organisms are also estimated (Mattick, *J. Dairy Research*, i., 2, 1930). Estimations of organisms fermenting milk sugar (coliform organisms) are of extreme value not only to the Health Authorities, but also to the milk producer and manufacturer. These organisms are not found in the udder, and since their presence can be shown by a simple technique they are valuable as indicators of contamination at some point during the handling of the milk. It should be noted that farm water supplies, which may contain numbers of coliform organisms, can infect milk if used for washing the udders of

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the cows. The old idea that the coliform organisms found in milk are necessarily of direct fæcal origin has long been proved to be erroneous, but in milk straight from the pail, examined at once, they probably indicate fæcal contamination. They are rarely in themselves of great importance, but have a deleterious influence upon the keeping quality of milk, and may be accompanied by pathogenic organisms from the cow's intestine. Evidence has been obtained that fæces may be the cause of intermittent contamination of milk by tubercle bacilli. Since the number of cows secreting infected milk from tuberculous udders is very small in proportion to the numbers of milking animals infected with the disease in other parts of the body, it would appear that the universal adoption of clean milking methods, designed to exclude contamination with fæces and other extraneous matter, would immediately result in a decrease in the number of samples of milk containing living tubercle bacilli.

Pasteurization—In recent years there has been a large increase in the quantity of milk treated by heat before distribution to the consumer. The process now universally recognized as the most desirable consists in heating milk at 145° F. for thirty minutes. There are certain practical difficulties in ensuring that the whole of the milk under treatment reaches and is maintained at this temperature owing to foam formation and the presence, in some types of apparatus, of "dead ends." By pasteurization the keeping quality of the milk is improved owing to the destruction of the greater part of the bacterial flora, including pathogens. In practice, however, it is found that a proportion of the non-pathogenic types present always resist pasteurization, and only some 99·5 to 99·7 per cent. of bacteria are actually killed. It has been recognized, therefore, that it is as essential to secure raw milk of low bacterial content for pasteurization as for distribution as raw milk.

Much of the good accomplished by pasteurization in the past has been negatived by subsequent contamination from coolers and containers, such as bottles, which have been imperfectly cleansed. It is very essential to secure sterility of such apparatus, which is capable of seriously contaminating the milk.

Although most organisms are killed by pasteurization, those which form spores are largely unaffected. In most cases the rate of action of these organisms on milk is too slow to be of practical importance, but recently, under the name "thermophils," types of bacteria have been described (Ayers and Johnson, *J. Bact.*, ix., 285, 1924) which not only survive, but grow at pasteurization temperatures. In the ordinary method of plating, these organisms do not grow, and therefore escape detection. It is necessary, therefore, to plate pasteurized milk on special media and incubate at 56° C. in order to demonstrate their presence. From time to time serious loss of milk is reported owing to coagulation produced by thermophils, especially where the heating process has been unavoidably prolonged because of a mechanical breakdown.

MILK AND MILK PRODUCTS, BACTERIOLOGY OF (*Continued*)—

Thermoduric Organisms—In addition to the small proportion of organisms in any mixed milk flora, which, as mentioned above, usually survive pasteurization, there occur, more or less frequently, some strains of non-sporing organisms, such as *Streptococcus lactis* and coliform organisms, of which a large proportion survives pasteurization and under suitable conditions causes premature souring of pasteurized milk (Ayers and Johnson, *J. Agric. Res.*, ii., 321, 1914). This type of organism is by no means rare, and furnishes an additional incentive to the provision of clean milk for pasteurization.

The streptococci surviving heat are in many cases the cause of the minute or pin-point colonies which cause trouble in counting when pasteurized milk is plated on ordinary standard agar.

Pasteurization of Milk Products—The deleterious effect of the growth of extraneous bacteria upon the quality of milk products has led to the use of pasteurization in manufacturing processes. In factory-made butter, for example, cream is always pasteurized before the addition of starter, which then has a clear field. In cheese-making also, pasteurization is largely used. The differences in the process of manufacture and in the quality of the final product make it obvious, however, that pasteurization should only be used in cheese-making pending the improvement of the raw milk supplies. Similarly, the materials used in the process of ice cream manufacture are pasteurized before use.

In the manufacture of sweetened condensed milk, in which about 2·75 volumes of milk are reduced to 1 volume by evaporating *in vacuo*, the temperature does not rise above 50° C., so that in the actual process of condensation little or no destruction of micro-organisms takes place. The flora of milk of this type is, therefore, somewhat large and diversified. Until the condensed milk is diluted these organisms do not grow because of the high concentration of added sugar. In the preliminary process as many as possible of the bacteria in the original milk, as well as some of the enzymes, are destroyed by pasteurization.

Sterilization—Although it is seldom possible under practical working conditions to secure real sterility or complete freedom from micro-organic life, it is quite possible, with simple apparatus, to approximate closely to this ideal, by heating to at least the boiling point of water for a definite time.

In recent years a great increase in the use of steam on farms and in dairies has taken place. This method of sterilization, when carefully applied and controlled, is very efficient and is the most fool-proof yet devised. Steam is universally used for sterilizing dairy utensils, bottles, and equipment, which, after treatment at 210° F. for ten minutes, will contain few if any living micro-organisms. The "boiling" water method of sterilization formerly advocated has had to be abandoned because in practice it has been found to be virtually impossible, in the absence of a steam heater, to apply really boiling water. Water at any lower temperature is comparatively inefficient and impossible for any large number of utensils. The use of disinfectants for farm pur-

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poses is officially discouraged because of the danger of contaminating the milk. Although in expert hands and with very thoroughly washed apparatus they may be efficient, the ease with which they may be badly applied in practice does not encourage their use for general dairy purposes.

Milking Machines—For many years milking machines were held in suspicion by farmers because of the experiences of their fellows. These machines are and have always been comparatively complicated, and failure to cleanse them thoroughly was the cause of their failure in practice. Milking machines have been enormously improved in recent years, and are now making rapid progress in this country. From the bacteriological standpoint they have manifest advantages over hand milking, since contamination from several possible sources is avoided. It has been shown both in America and Europe (Mattick and Procter, *J. Hygiene*, xxvii., 222, 1928) that if the machines are thoroughly washed and then sterilized by steam, milk of very low bacterial content can be secured at all seasons of the year. Some deterioration of the rubber naturally occurs, but modern rubber is of such excellent quality that the effects of steam, even when rubber and metal are in contact, are not so serious as to preclude its use; if the rubber parts are sterilized out of contact with metal, steam appears to be no more deleterious than hot water, which is much less efficient for this purpose.

Sterilized Milk—A large quantity of milk is sold in London and the Midlands after being heated in bottles at temperatures of 100° C. or more for periods varying from twenty minutes to half an hour. Very high temperatures are not practicable, because of serious changes in flavour and appearance caused by treatment at these temperatures. In actual fact most of the milk sold as " sterilized milk " is not sterile.

Certain spore-forming organisms survive and cause serious losses in the trade, especially in summer, owing to the production of taints due to the formation of traces of phenol and changes in the milk fat (Mattick, *Analyst*, January, 1930; Hiscox, *Dairyman*, December, 1930).

Non-spore-forming bacteria which are sometimes found are probably contaminations subsequent to heating.

Evaporated Milk—Another dairy product, to which a temperature of 100° C. or over is applied, is the so-called evaporated milk. Practically the only organisms surviving the process are spore-formers, and of these only the anaerobes cause trouble. The author has investigated several cases in which *Clostridium putrificum*, the spores of which are very difficult to destroy in milk, has caused severe loss owing to the production of gas and foul-smelling compounds, rendering the milk useless.

Cultured Milk—With the possible exception of the limited flora of the healthy udder, it is true to say that there are no " milk bacteria," but certain types, owing to their very frequent presence in milk, have acquired that title. Conspicuous amongst these are the lactic acid producing bacteria, such as *Streptococcus lactis, Lactobacillus bulgaricus*, and *Lactobacillus acidophilus*.

MILK AND MILK PRODUCTS, BACTERIOLOGY OF (*Continued*)—

Streptococcus lactis—This organism, the usual cause of souring, grows luxuriantly in milk when temperatures are favourable, produces lactic acid from milk sugar, and coagulates the milk. It is, therefore, a nuisance to the vendor of whole milk, and must be excluded. In butter and cheese making, however, advantage is taken of its acid-producing properties to secure, by its aid, the conditions necessary for manufacture. In butter making, cultures of *S. lactis* and the similar *S. cremoris* are used to enhance flavour which arises from traces of substances produced as by-products of the lactic acid fermentation. Although excellent butter can be made from cream soured with these organisms, the keeping quality on long storage is found to be affected, and research is, therefore, being directed to the problem of securing flavour without deleterious acidity.

In cheese making, *S. lactis* is added to the milk to raise the acidity to a point favourable for coagulation by rennet, and by its vigorous growth to suppress undesirable contaminants. In practice it is often found that a culture rapidly loses its vigour and fails to produce acidity or becomes "slow working." These defects spoil the final product. The exact reason for slow working is at present not known, but there is reason to believe that deficiencies in the milk itself in some cases, and antagonistic growth of contaminants in others, are connected with the trouble. Several workers have shown that the milk of some cows which was normal failed to support the growth of *S. lactis*, but the addition of yeast extract repaired the deficiency.

Lactobacillus bulgaricus and *Lactobacillus acidophilus*—These organisms, which are typical of a group of organisms commonly found in milk, usually grow only after *S. lactis* has raised the acidity to about 1 per cent. and then died. They produce up to about 3 per cent. lactic acid, and are, therefore, being increasingly used in England as therapeutic drinks. Although *L. bulgaricus* was formerly believed to implant itself in the intestine, to the exclusion of the undesirable flora, it has now been shown (Rettger and Cheplin, *Yale Univ. Press*, 1921) that only *L. acidophilus* is capable of so establishing itself.

Milk, separated milk, or whey cultures of these organisms are now on the market. It has been found, however, that strict laboratory control is necessary to ensure the continued purity of the cultures.

Streptococcus citrovorus and *Streptococcus paracitrovorus*—These organisms, which are true lactic acid bacteria, have been advocated as desirable additions to butter starters on account of their production, from the citric acid of milk, of traces of substances which improve the flavour and aroma. Recent attempts (Maddock, *J. Dairy Res.*, ii., 203, 1931), to use these organisms in pure culture failed in most cases because of the low acid production and inability to combat contaminants. An occasional strain of *S. paracitrovorus*, however, was found to produce almost as much acid as *S. lactis*. Maddock found that in solid media, yeast extract produced massive growth of these organisms. This offers confirmation of the fact previously observed that bacteria require certain "factors," as yet ill defined or unknown in composition, for their optimum growth.

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Although the true lactic acid bacteria are characterized by their vigorous action on milk sugar with the production of lactic acid, they are, contrary to the general belief, capable of causing proteolysis or protein splitting. This action is very slow and of no importance in dairy products which are consumed quickly. In cheese, however, it has considerable importance, because it takes part in the ripening process, and helps to split up the casein into soluble and digestible compounds. Orla Jensen states that the lactobacilli are unable to use complete proteins, and the enzyme responsible for casein splitting is active only on liberation from the organisms after death.

Gorini found that some of the udder cocci are able to cause proteolysis in an acid medium. This has hitherto been regarded as doubtful or impossible.

Bacterial Association—There is evidence that the growth of lactic acid bacteria only becomes rapid when the milk has been slightly acted upon, or has been physically changed by the previous growth of other bacteria. Marshall (*J. Dairy Sci.*, iii., 413, 1920) asserts that *B. subtilis*, a proteolytic spore former, enhances the growth of *S. lactis*.

This associated growth of bacteria is an aspect of the subject which has been neglected in milk bacteriology. It undoubtedly has great significance in the study of faults in milk and milk products, and may throw light on the problem of cheese ripening.

Davis and Mattick (*J. Dairy Res.*, vol. i., 1 and 2, 1929, 1930) found in studying the cause of "rusty spot" in Cheddar cheese that the causative organism failed to produce pigment readily in sterile milk, but that good pigment was secured by allowing a variety of common milk bacteria to grow with it, or by adding certain substances of unknown composition. It may well be that adjustments of the physico-chemical constitution of the medium, *e.g.*, the oxidation-reduction potential, by an organism growing in it, may influence the growth of other organisms.

The author found that oxidation of milk fat (oiliness in milk) induced by traces of copper derived from untinned utensils was inhibited by *S. lactis* and *B. coli*, which rapidly reduced the oxidation-reduction potential, but not by the yeasts and non-acid-producing cocci usually found in oily milk, and was able to correlate the findings with oxidation reduction potentials induced by the organisms.

There seems to be no doubt that a study of bacterial association and the physico-chemical characteristics of milk and its products offers a wide field for investigation, with promise of contributing to the solution of the complex problems of conservation and storage. For example, Rahn and Boysen (*Milch. Forsch.*, vii., 1-2, 214, 1928), by a study of the size and distribution of water droplets, supplied an explanation of the fact that bacteria do not normally grow in butter, owing to the small size of many of the water droplets, while the larger ones were found to be deficient in bacterial nutrients. Moulds, and perhaps yeasts, owing to their greater size and different mode of development, can grow from droplet to droplet, and therefore increase in numbers in butter.

MILK AND MILK PRODUCTS, BACTERIOLOGY OF (*Continued*)—

The appearance of pink and yellow discolouration in hard and half pressed cheese has been shown (Mattick and Williams, *Biochem. J.*, xv., 2, 1921) to be intimately connected with the reaction (acidity or alkalinity) of the curd which inhibits or permits the growth of these organisms which produce the substances from which the pink compounds are synthesized. A. T. R. M.

MILK, BUTTER—The liquid found in the churn after the process of churning is finished is called butter-milk.

In England it is often diluted with the water used in the last stages of butter making.

Undiluted, genuine butter-milk gives a proximate analysis similar to sour separated milk, but it contains more fat (about 0·5 per cent.). It has a distinctive smell and flavour which distinguish it from sour separated milk. A more detailed comparative study of butter-milk from cream and from artificial cream might be of value as a means of distinguishing the latter.

Butter-milk has a long-standing reputation as a beverage, and should be distinguished from pasteurized and soured separated milk, which is sometimes offered as a commercial substitute.

Condensed butter-milk and a powder sold as dry butter-milk have recently been put on the market, and high nutritive values are claimed for these products for pig feeding and other purposes.

Unpublished feeding experiments on pigs support these claims, but the high price makes them of more doubtful economic value. J. G.

MILK, CULTURED—See Milk and Milk Products, Bacteriology of.

MILK, EVAPORATED—See Milk and Milk Products, Bacteriology of.

MILK, SEPARATED, AND SKIM—This liquid contains all the constituents of milk, except the cream, from which it is now usually divided by means of centrifugal force in a separator (*q.v.*). Separated milk is not so rich in fat as skim milk from which the cream has been allowed to rise, on standing either in the cold or in the case of "Devonshire cream" after scalding.

The average composition of separated milk is:

	Per Cent.
Water	90·58
Fat	0·12
Milk sugar	4·95
Casein	3·15
Albumin	0·42
Ash	0·78

Separated milk is a good food for animals, but the removal of the fat with its associated "fat-soluble" vitamins A and D (see Foods and Feeding, Scientific Principles of) reduces its nutritive value as compared with whole milk. This is more especially important where other sources of these necessary factors are wanting. Separated milk fed in large quantities has been observed to favour the development of rickets in pigs.

MILK, SEPARATED, AND SKIM (*Continued*)—

The addition of cod-liver oil will replace the vitamins removed with the cream.

The Sale of Milk Regulations, 1912, provide that "where a sample of skimmed or separated milk (not being condensed milk) contains less than 8·7 per cent. of milk solids other than milk fat, it shall be presumed . . . that . . . it is not genuine."

Separated milk, and also dried or condensed separated milk, is now used in large quantities for bread making and in the confectionery trade.

It is for this purpose that separated milk is dried to a powder on roller driers heated with steam, or spray dried where larger quantities are available. Unsweetened separated milk is also condensed, and much of this product is imported. J. G.

MILK, LEGAL PROVISIONS RELATING TO THE PRODUCTION AND SALE OF. Provisions to Ensure the Sale of Milk without Abstraction of Milk Fat or Milk Solids, or Addition of Water or other Adulteration—Milk is included in the expression "Food" contained in the Food and Drugs (Adulteration) Act, 1928, which states: "The expression 'food' includes every article used for food or drink by man, other than drugs and water, and any article which ordinarily enters into or is used in the composition or preparation of human food, and also includes flavouring matters and condiments." By section 2 of that Act no person shall sell to the prejudice of the purchaser any article of food which is not of the nature, substance, or quality of the article demanded by the purchaser. Where a seller professes to sell a particular article, and sells one materially altered by admixture, he will be deemed to have sold the article to the prejudice of the purchaser unless the condition of the article has been brought to the notice of the purchaser before sale, or must be taken to have been so brought to his knowledge by means of a proper label affixed thereto or otherwise. An offence under this section may be established if it is shown that an ordinary purchaser would be prejudiced by the sale, even though the actual purchaser may not be prejudiced, but no offence is deemed to be committed where food is unavoidably mixed with some extraneous matter in the process of collection or preparation. A person found guilty of such offence is liable on conviction—

(*a*) in the case of a first offence, to a fine not exceeding £20; and
(*b*) in the case of a second offence, to a fine not exceeding £50; and
(*c*) in the case of a subsequent offence, to a fine not exceeding £100;

or if, in the opinion of the court, the offence was committed by the personal act, default, or culpable negligence of the person accused, and the court is of opinion that a fine will not meet the circumstances of the case, to imprisonment for a term not exceeding three months.

For the purpose of providing proper securities for the sale of food and drugs in a pure and genuine condition, the Food and Drugs (Adulteration) Act, 1928, directs that certain local authorities shall

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

be the Food and Drugs Authorities for their particular areas. In county boroughs, and in many other boroughs, the council of the borough is the Food and Drugs Authority; with respect to any other area, excepting the City and County of London, the Authority is the county council. It is the duty of every Food and Drugs Authority from time to time to put in force the powers vested in them as occasion may arise, for which purpose they must retain the services of a competent person as Public Analyst, and direct their officers to procure samples for analysis.

A sampling officer may take at the place of delivery any sample of milk in course of delivery to the purchaser or consignee in pursuance of any contract for the sale thereof to the purchaser or consignee. If the name and address of the consignor is discernible on the milk can the officer taking the sample must forward to the consignor a portion of the sample marked, and sealed, or fastened up.

It is an offence under the Act for any person having milk exposed for sale or on sale by retail to refuse to supply a sampling officer with such quantity as is reasonably requisite for the purpose of analysis, provided he tenders the price for the milk, the person so refusing being liable to a fine not exceeding £10. It is a similar offence to refuse to allow a sampling officer to take a sample of milk in course of delivery in pursuance of a contract for sale thereof. On proceedings being taken for either of these offences it is no defence for the defendant to allege that he did not know the person demanding the milk to be supplied to him was a sampling officer, such officer being under no obligation to produce his authority if it is not demanded.

A private individual who has purchased milk may take proceedings for alleged adulteration under the Act of 1928, and a conviction may be recorded where sufficient evidence is forthcoming to substantiate the charge. In the case of a sampling officer, either personally or through an agent, purchasing a sample of milk with the intention of submitting it to analysis, however, he is required by section 18 of the Act, after the purchase has been completed, forthwith to notify to the seller or his agent who sold the sample his intention to have it analysed by the public analyst, and then and there to divide the sample into three parts, marking and sealing or fastening up each part, and—

(*a*) if required to do so, deliver one part to the seller or his agent,
(*b*) retain one part for future comparison,
(*c*) if he thinks fit to have an analysis made, submit one part to the analyst,

and, in such a case, no person may be convicted on the ground that the sample sold is not of the nature, substance, or quality demanded if the requirements of this section have not been complied with, or if proceedings have not been instituted within twenty-eight days from the time of the purchase of the sample.

In any proceedings for an offence under the Act, where a certificate of analysis has been obtained on behalf of a prosecutor, a copy thereof

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—
must be served with the summons; and, if a defendant intends to produce a copy of a certificate of a public analyst, a copy thereof must be sent to the prosecutor at least three days before the day fixed for the hearing of the case, failing which the court may, if it thinks fit, adjourn the hearing on such terms as it may deem proper. The production by either of the parties of a certificate of a public analyst in the form prescribed by the Act is sufficient evidence of the facts stated therein unless the other party requires that the analyst shall be called as a witness.

The Minister of Agriculture and Fisheries is authorized by section 7 of the Act of 1928 to make regulations for determining what deficiency in any of the normal constituents of genuine milk shall for the purpose of the Act raise a presumption, until the contrary is proved, that the milk is not genuine or is injurious to health, and an analyst must have regard to such regulations in certifying the result of an analysis under the Act. This section reimposes the power to make such regulations conferred by the Sale of Food and Drugs Act, 1899. The Act of 1899, and many other enactments relating to the provision and sale of milk, were repealed by the Act of 1928, but the repeals do not affect regulations and orders made under the repealed enactments. No regulations having yet been made under the Act of 1928, the Sale of Milk Regulations, 1901 are still operative whereby a presumption is raised that milk is not genuine if it contains less than 3 per cent. of milk fat and 8·5 per cent. of milk solids.

When a presumption has been raised that milk is not genuine by reason of its deficiency in milk fat or milk solids, the burden is upon the defendant of showing that there has been no addition to, or subtraction from, the milk from the time of milking to delivery, unless he has purchased the milk under a written warranty that it was the same in nature, substance, and quality as that demanded of him by the person to whom he sold it. It is no offence under this Act to sell milk in the same state as it came from the cow, even though there may be a deficiency in milk fat or milk solids caused by improper feeding; but when cream collects naturally at the top of a churn and the milk is drawn from a tap at the bottom of the churn without being stirred the milk is not sold in the same state as it came from the cow, and the seller will be liable to conviction if the failure to stir the milk has caused a deficiency in milk fat or milk solids.

A defendant relying upon his having purchased milk under a written warranty as aforesaid as a defence to proceedings taken under the Act must prove to the satisfaction of the court that he had no reason to believe at the time he sold the milk that it was not of the nature, substance, and quality warranted; and that he sold it in the same state as when he purchased it. The warranty is only a defence to proceedings under the Act if—

(*a*) the defendant has within seven days of the service of the summons sent to the prosecutor a copy of the warranty with a written notice stating that he intends to rely on it, and specifying the name

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

and address of the person from whom he received it, and has also sent a like copy of his intention to that person; and

(*b*) in the case of a warranty given by a person resident outside the United Kingdom the defendant proves that he has taken reasonable steps to ascertain, and did in fact believe in, the accuracy of the statement contained therein; and

(*c*) in the case of a prosecution in England or Wales in respect of a sample of milk, the defendant has within sixty hours after the sample was procured served on the local authority a notice stating the name and address of the seller from whom he received the milk and the time and place of delivery to him by the seller or consignor of milk from a corresponding milking, and requesting them to take immediate steps to procure, as soon as practicable, a sample of milk in the course of transit or delivery from the seller or consignor to him, unless a sample has been so taken since the sample was procured from him, or within twenty-four hours prior to the sample being procured from him.

Where the defendant is a servant of the person who purchased the milk under a warranty he is entitled to rely on the above provisions in the same way as his employer would have been entitled to do if he had been the defendant, provided that the servant further proves that he had no reason to believe the milk was otherwise than that demanded by the purchaser.

A servant selling milk on behalf of his master is liable to be convicted under this Act; but the master may be liable to a penalty under the Act, as a seller of milk, even though he prove that the milk had been adulterated by his servant without his knowledge. Such evidence, however, is admissible with a view to mitigation of penalty.

A local authority may, instead of, or in addition to, taking proceedings against a purveyor of milk, take proceedings against the seller or consignor. If a sample of milk of cows in any dairy is taken in course of transit or delivery from that dairy, the owner of the cows may, within sixty hours after the sample of milk was procured, serve on the local authority a notice requesting them to take immediate steps to procure as soon as practicable a sample of milk from a corresponding milking of the cows.

Provisions for the Making of Milk and Dairies Orders and the Prevention of the Supply of Milk Dangerous to Health—The Minister of Health, with the concurrence of the Minister of Agriculture and Fisheries, is empowered, by the Milk and Dairies (Consolidation) Act, 1915 (section 1), to make milk and dairies orders as he thinks fit, for all or any of the following purposes:—

(*a*) for the registration with local authorities of all persons carrying on the trade of dairymen;

(*b*) for the registration with local authorities of all dairies;

(*c*) for the inspection of cattle in dairies;

(*d*) for the inspection by persons authorized by the local authority for the locality in which the dairy is situate of dairies and persons in

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

or about dairies who have access to the milk or to the churns or other milk receptacles;

(*e*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of dairies in the occupation of persons following the trade of dairymen;

(*f*) for securing the cleanliness of milk stores, milk shops, and milk vessels used for containing milk for sale by such persons;

(*g*) for prescribing the precautions to be taken for protecting milk against infection or contamination;

(*h*) for preventing danger to health from the sale for human consumption, or from the use in the manufacture of products for human consumption, of infected, contaminated, or dirty milk;

(*i*) for regulating the cooling, conveyance, and distribution of milk intended for sale for human consumption, or for use in the manufacture of products for human consumption;

(*j*) as to the labelling, marking, or identification, and the sealing or closing of churns, vessels, and other receptacles of milk for sale for human consumption or used for the conveyance of such milk;

(*k*) for prohibiting the addition of colouring matter; and for prohibiting or regulating the addition of skimmed or separated milk or water or any other substance to milk intended for sale for human consumption, or the abstraction therefrom of butter fat or any other constituent; and for prohibiting or regulating the sale for human consumption of milk to which such an addition or from which such abstraction has been made, or which has been otherwise artificially treated;

(*l*) for authorizing the use, in connection with the sale of milk, of the designation "certified milk," for prescribing the conditions subject to which milk may be sold under such designation, and for prohibiting the use of such designation in connection with the sale of milk in respect of which the prescribed conditions are not complied with;

(*m*) for authorizing a local authority to make regulations for the purposes aforesaid, or any of them, subject to such conditions (if any) as the Minister of Health prescribes.

Any person guilty of a contravention of, or non-compliance with, the provisions of any Milk and Dairies Order is guilty of an offence against the Act. All Milk and Dairies Orders made under the Act have to be laid before each House of Parliament as soon as may be after they are made, and if either House, within a specified time, present an address to His Majesty praying that an order may be annulled, such order shall thenceforth be void, but without prejudice to the validity of anything previously done thereunder, or to the making of a new order.

The Act of 1915 did not come into operation until the 1st September, 1925, and in the following year an order was made by the Minister of Health, known as the Milk and Dairies Order, 1926, dealing with many of the matters above enumerated.

In order to prevent milk being supplied which may be injurious to health, the Act of 1915 provides that if a person—

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

(*a*) Sells or offers or exposes for sale, or suffers to be sold or offered or exposed for sale, for human consumption or for use in the manufacture of products for human consumption; or

(*b*) Uses or suffers to be used in the manufacture of products for human consumption;

the milk of any cow which has given tuberculous milk, or is suffering from emaciation due to tuberculosis, or from tuberculosis of the udder, acute inflammation of the udder, acute mastitis, actinomycosis of the udder, anthrax, foot-and-mouth disease, suppuration of the udder, or any other disease affecting cows which by a Milk and Dairies Order is declared to be a disease for this purpose, he shall be guilty of an offence against the Act, if it is proved that he had previously received notice from an officer of a local authority, or that he otherwise knew, or by the exercise of ordinary care could have ascertained, that the cow had given tuberculous milk, or was suffering from any such disease.

If the Medical Officer of Health of any county, county borough, or non-county borough whose council are directed to exercise the powers of a county council for this purpose, is of opinion that tuberculosis is caused, or is likely to be caused, by the consumption of the milk supplied from any dairy in which cows are kept within such county or borough, it is his duty to send a report on the matter to the council accompanied by the veterinary or bacteriological reports which have been furnished to him. On the receipt of the report the council may, after furnishing the dairyman with a copy of the reports and giving him an opportunity to appear before them or furnish an explanation in writing, make an order prohibiting him, either absolutely or unless certain conditions as may be prescribed are complied with, from supplying for human consumption, or using or supplying for use in the manufacture of products for human consumption, any milk from the dairy or from any particular cow or cows therein. If an order is made it must specify the grounds on which it is made, a copy of the order must be forthwith served on the dairyman and notice of the facts are to be served on the Minister of Health and the Minister of Agriculture and Fisheries. As soon as may be after the council or their Medical Officer of Health is satisfied that the milk supplied from the dairy is not likely to cause disease the order must be withdrawn and notice of withdrawal served on the dairyman. Where no order is made the dairyman is entitled to reasonable expenses incurred by him in showing cause why the order should not be made. If a dairyman is aggrieved by the making or continuance of any such order he may appeal to a court of summary jurisdiction, who may confirm, vary, or withdraw the order. A dairyman is entitled to full compensation for damage or loss which he may have sustained by reason of the making of an order prohibiting him from supplying or using milk as aforesaid, unless the order has been made in consequence of his own fault or neglect; he is also entitled to compensation if the council unreasonably neglect or refuse to withdraw an order made

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

against him; also, whilst such an order is in force he is not liable for an action for breach of contract if the breach is due to such order.

An Inspector of the Minister of Health and any person authorized by such Inspector, also the Medical Officer of Health or any person authorized by him, or the council, within the area of the council, may take for examination samples of milk at any time before it is delivered to the consumer. The result of an analysis or bacteriological or other examination of a sample of milk taken under the Milk and Dairies (Consolidation) Act, 1915, is not admissible as evidence in proceedings under that Act unless the provisions of the Food and Drugs (Adulteration) Act, 1928, relating to the division of samples into parts, as before referred to, are complied with; but if such provisions are complied with, the result of the analysis is available for proceedings under the Act of 1928 as well as under the Act of 1915, save that no proceedings may be taken under the Act of 1915 against any person unless at the time the sample was taken the milk was in his custody or control, or was contained in a receptacle which had been sealed or closed in accordance with a Milk and Dairies Order.

A person committing an offence against the Act of 1915 is liable on conviction to a fine not exceeding in the case of a first offence £5, and in the case of a second or subsequent offence £50, and if the offence is a continuing offence to a further fine not exceeding forty shillings for each day during which the offence continues. When it is made to appear to the satisfaction of the authority by or on whose behalf proceedings are about to be taken—

(*a*) that the actual occupier of the dairy has used all due diligence to enforce the execution of this Act and the Milk and Dairies Orders; and

(*b*) by what person the offence has been committed; and

(*c*) that it has been committed without the knowledge, consent, or connivance of the occupier of the dairy and in contravention of his orders—

proceedings are to be taken against the person who is believed to be the actual offender without first proceeding against the occupier of the dairy. Further protection under this Act is afforded to the occupier of a dairy by enabling him, when charged with an offence against the Act, to lay information to have any other person whom he charges as the actual offender brought before the court at the time appointed for hearing the charge; and if, after the commission of the offence has been proved, the occupier of the dairy proves to the satisfaction of the court—

(*a*) that he has used due diligence to enforce the execution of the Act and the Milk and Dairies Orders; and

(*b*) that the said other person had committed the offence in question without his knowledge, consent, or connivance;

that other person shall be convicted of the offence, and the occupier shall be exempt from any fine.

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

The Milk and Dairies (Amendment) Act, 1922, authorizes any local authority by whom a register of purveyors of milk is kept to refuse to register any person as a retail purveyor of milk, or to remove a purveyor from the register, as the case may be, if they are satisfied that the public health is or is likely to be endangered by any act or default of such person. Before refusing to have a name on the register a notice must be served on the person concerned setting out the reasons for such refusal, and he must be given an opportunity to show cause why the local authority should not make the refusal. Any person aggrieved by any decision of the local authority may appeal to a court of summary jurisdiction, and either party may appeal from the decision of such court to Quarter Sessions. Where the registration of a retailer is refused, or a retailer is removed from a register, under this Act, the retailer is not liable in any action for breach of a contract for the purchase of further supplies of milk from a producer, if he can prove that such refusal or removal was due to the quality of milk supplied by the producer.

The Act of 1922 increases the maximum penalty for the offence of selling, offering, or exposing for sale the milk of a cow suffering from tuberculosis of the udder, to a fine not exceeding £20 for the first offence, and for a second or subsequent offence to a fine not exceeding £100 or imprisonment with or without hard labour for a period of six months, or to both such fine and imprisonment.

Licences to Sell Milk under Special Designations—By section 3 of the Milk and Dairies (Amendment) Act, 1922, no person may, unless in accordance with a licence granted by the Minister of Health, or with his authority under the provisions of an order made by him under the Act—

(*a*) sell or offer or expose for sale any milk as "Certified," "Grade A," "Pasteurized," or under such other designation as may be from time to time prescribed by order of the Minister; or

(*b*) on or in connection with any sale or offer for sale or proposed sale of any milk, or in any advertisement, circular, or notice relating to any milk, describe or refer to the same as "Certified," "Grade A," "Pasteurized," or by any other designation described as aforesaid, or use any description or designation including or resembling any such description or designation.

An order made by the Minister of Health under the above section specifying the terms and conditions under which licences may be granted, known as "The Milk (Special Designations) Order, 1923," came into operation on the 1st July, 1923. The special designations under which milk may be sold or offered or exposed for sale in pursuance of this Order are:—"Certified," "Grade A (Tuberculin tested)," "Grade A" and "Pasteurized."

Every county council and county borough is authorized to grant licences to producers to sell milk as "Grade A," and every district council is authorized to grant licences to any person to sell milk as "Pasteurized" and to any person to sell milk as "Certified," "Grade A

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

(Tuberculin tested)," or " Grade A," otherwise than from the establishment at which the milk is produced: Provided that in any case in which the Minister of Health is satisfied that a county council are unwilling or do not propose to exercise in any district the power of granting licences conferred on them, the Minister may authorize the district council to grant such licences in place of the county council. A licensing authority may delegate to a committee of the authority, with or without restrictions or conditions as they think fit, all or any of their powers under this Order, and two or more licensing authorities may concur in appointing out of their respective bodies a Joint Committee for carrying out their duties under the Order and conferring on any such committee any powers which the appointing authorities might exercise for the purpose.

Licences granted under the Order have to be in the form contained in the First Schedule thereto with such modifications, if any, as the circumstances may require, and every licence so granted is subject to conditions specified in the Order (see below). The local authority authorized to grant a licence must be satisfied by the applicant that his arrangements for the production, storage, treatment and distribution of the milk, as the case may be, are such as to comply with the conditions upon which the licence may be granted; Also, before granting a licence to a producer the licensing authority must require him in the case of " Certified " milk or " Grade A (Tuberculin tested) " milk to produce a veterinary surgeon's certificate showing the results of an examination of the herd carried out not more than three months before the date of the application and a certificate of a prescribed tuberculin test of the herd carried out within a similar period, and in the case of " Grade A " milk to produce a veterinary surgeon's certificate showing the results of an examination of the milch cows belonging to the herd carried out not more than one month before the date of the application.

Every licence granted under the Order is valid for a period ending on the 31st December in the year in respect of which it is granted. The fees payable for licences are set out in the Fourth Schedule to the Order, but where a licence is granted for a period of less than a year the licensing authority may grant the licence upon payment of such sum being less than the full fee as they think fit having regard to the period for which the licence will operate.

Notwithstanding anything contained in the Order, a licence permitting a producer to sell milk produced by him as " Certified " entitles him to sell such milk as " Grade A (Tuberculin tested) " or as " Grade A," and a licence permitting the producer to sell milk produced by him as " Grade A (Tuberculin tested) " entitles him to sell such milk as " Grade A."

A licensing authority may suspend or revoke a licence granted by them if they are satisfied that any of the conditions under which the licence has been granted are not being complied with, provided that they first serve a notice upon the holder specifying the grounds upon which it is proposed to suspend or revoke the licence and afford him

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

a reasonable opportunity of making such representations to the authority in regard thereto as he thinks fit. A person aggrieved by a decision of a licensing authority to refuse or to suspend or revoke a licence may within seven days after receiving notice of such decision appeal to the Minister of Health, whose decision is final. Pending the final determination of any appeal from a decision to suspend or revoke a licence, the licence continues to have effect.

The conditions to which licences are subject are set out in the Second and Third Schedules to the Order. The Second Schedule contains general conditions applicable to all licences granted under the Order, whilst the Third Schedule is divided into four Parts in accordance with the designations of milk prescribed by the Order. These schedules are as follows:—

SECOND SCHEDULE

General Conditions subject to which Licences may be Granted

(1) The arrangements and processes under and by which the milk is produced, stored, treated and distributed, as the case may be, shall be such as to satisfy the licensing authority that the conditions subject to which the licence is granted are being and will be complied with.

(2) The holder of the licence shall—

(*a*) take such measures as the licensing authority may require to ensure that the milk in respect of which the use of a special designation is authorized shall be kept separate at all stages from all other milk;

(*b*) keep accurate records of the quantities of milk produced, purchased and sold, as the case may be, and of the names and addresses of the persons from whom the milk was purchased and to whom it was sold otherwise than by retail;

(*c*) permit any person duly authorized by the licensing authority—

(i.) to inspect the processes of production, storage and treatment,

(ii.) to take samples of the milk free of charge, and

(iii.) to inspect any records which the holder is required by the conditions of the licence to keep.

THIRD SCHEDULE

PART I

Conditions subject to which Licences for selling Milk as "Certified" may be Granted

A.—*The following conditions apply to producers only*:—

(1)—(*a*) The producer shall cause every animal of the herd to be submitted to an examination and to a prescribed tuberculin test at intervals of six months and shall produce to the licensing authority the veterinary surgeon's certificate and the certificate of the prescribed

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

tuberculin test within seven days after the respective dates of those certificates. He shall not permit any animal to be injected with tuberculin except on the occasions of the prescribed tuberculin tests;

(*b*) No animal other than an animal taken directly from a herd in respect of which a licence for the sale of "Certified" or "Grade A (Tuberculin tested)" milk is in operation shall be added to the herd unless it has passed a prescribed tuberculin test immediately before it is so added;

(*c*) Where any animal is certified as reacting to a prescribed tuberculin test it shall forthwith be removed from the herd, and where any animal is certified as showing evidence of any disease which is likely to affect the milk injuriously it shall be isolated or removed from the herd, as the case may require. The milk from an animal so isolated shall not be sold as milk from the herd. The producer shall inform the licensing authority of the reasons for the isolation or removal of an animal and, in the case of removal, of the manner in which it has been disposed of;

(*d*) A suitable system shall be adopted for the marking for purposes of identification of the animals in the herd, and a complete register of such animals shall be kept; and

(*e*) The herd shall be completely isolated from all other cattle.

(2) The milk shall be bottled on the farm immediately after production.

(3) Every bottle containing the milk shall be closed with a suitable tightly fitting disc and covered with a suitable outer cap overlapping the lip of the bottle and so fastened as to form a complete seal. The cap shall bear the name and address of the producer or of the dairy where the milk is produced, the day of production and the words "certified milk." The words "produced from cows which have passed the tuberculin test" may be added, but, except with the consent of the licensing authority, the cap shall bear no other words.

B.—*The following conditions apply to all holders of licences to sell milk as "Certified":—*

(1) The milk shall not be removed from the bottles or the seals broken before delivery to the purchaser.

(2) On a sample being taken at any time before delivery to the consumer the milk shall be found to contain:—

(*a*) not more than 30,000 bacteria per cubic centimetre; and
(*b*) no coliform bacillus in one-tenth of a cubic centimetre.

(3) The milk shall not at any stage be treated by heat.

PART II

Conditions subject to which Licences for selling Milk as "Grade A (Tuberculin tested)" may be Granted

(1) The conditions set out in paragraph (1) of sub-division A of Part I, in paragraph (7) of sub-division A of Part III, in sub-division B of Part III, and in paragraph (2) of sub-division C of Part III, of

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

this Schedule shall apply with the substitution in Part III of the designation "Grade A (Tuberculin tested") for the designation "Grade A."

(2) The milk shall not at any stage be treated by heat.

PART III

Conditions subject to which Licences for selling Milk as "Grade A" may be Granted

A.—*The following conditions apply to producers only:*—

(1) No animal which to the knowledge of the owner of the herd has at any time been tested with tuberculin and has reacted to the test shall form part of or be added to the herd.

(2) The producer shall cause every milch cow belonging to the herd to be examined once in every three months, and shall produce to the licensing authority the veterinary surgeon's certificate within seven days after the date of the certificate.

(3) Where any animal is certified as showing evidence of any disease which is likely to affect the milk injuriously it shall be isolated or removed from the herd, as the case may require. The milk from an animal so isolated shall not be sold as milk from the herd. The producer shall inform the licensing authority of the reasons for the isolation or removal of an animal and, in the case of removal, of the manner in which it has been disposed of.

(4) If at any time it is shown to the satisfaction of the licensing authority that tubercle bacillus is contained in the milk, the producer shall take all necessary steps to ascertain which animals are diseased and to remove them from the herd and shall inform the licensing authority how such animals have been disposed of.

(5) A suitable system shall be adopted for the marking for the purposes of identification of the milch cows belonging to the herd, and a complete register of such cows shall be kept.

(6) The cows in milk belonging to the herd shall be kept separate from all other cows in milk.

(7) Except where the milk is bottled by the producer in accordance with the procedure for bottling hereinafter specified, the milk shall be consigned from the dairy where it is produced in an unventilated sealed container which shall be labelled or marked in a suitable manner with the address of the dairy, the day of production (with the word "morning" or "evening" according to the time of milking) and the words "Grade A Milk."

B.—*The following conditions apply to persons other than producers:*

(1) Except where the milk is delivered to the consumer in the containers in which it is received, the seals being unbroken, it shall be delivered either in bottles or in other suitable containers of not less capacity than 2 gallons.

(2) Every bottle containing the milk shall be closed with a suitable tightly fitting disc and covered with a suitable outer cap overlapping

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

the lip of the bottle and so fastened as to form a complete seal. The cap shall bear the name of the dealer by whom the milk was bottled, and the address of the licensed bottling establishment, the words "Grade A Milk" and the day of production, and shall except with the consent of the licensing authority bear no other words. Where containers other than bottles are used, every container shall be closed with a tightly fitting cover and shall be suitably sealed and labelled.

C.—*The following conditions apply to all holders of licences to sell milk as "Grade A":—*

(1) The milk shall not at any stage be treated by heat unless a licence to sell such milk as "Pasteurized" has been granted under this Order, and where such a licence has been granted the term "Pasteurized" shall be added after the designation "Grade A Milk" wherever such designation is used in connection with the sale of such milk or the labelling or marking of receptacles containing such milk.

(2) Milk sold as "Grade A Milk" shall be produced and treated under such conditions that on a sample being taken at any time before delivery to the consumer the milk shall be found to contain:—

(*a*) not more than 200,000 bacteria per cubic centimetre; and
(*b*) no coliform bacillus in one-hundredth of a cubic centimetre.

(3) Milk sold as "Grade A Milk Pasteurized" shall be produced and treated under such conditions that on a sample being taken before delivery to the consumer the milk shall be found to contain:—

(*a*) in the case of a sample taken at any time before the 1st day of January, 1924, not more than 50,000 bacteria per cubic centimetre, and no coliform bacillus in one-hundredth of a cubic centimetre; and

(*b*) in the case of a sample taken at any time after the year 1923 not more than 30,000 bacteria per cubic centimetre, and no coliform bacillus in one-tenth of a cubic centimetre.

PART IV

Conditions subject to which Licences for selling Milk as "Pasteurized" may be Granted

(1) The milk shall be pasteurized, that is to say, retained at a temperature of not less than 145° and not more than 150° Fahrenheit for at least half an hour, and be immediately cooled to a temperature of not more than 55° Fahrenheit.

(2) The milk shall not be so heated more than once and shall not be otherwise treated by heat.

(3) The type of apparatus used for pasteurizing and the methods employed shall be such as are satisfactory to the licensing authority.

(4) Every vessel containing the milk shall bear a suitable label with the words "Pasteurized Milk."

(5) On a sample of the milk being taken after pasteurization and before delivery to the consumer, the milk shall be found to contain:—

MILK, LEGAL PROVISIONS RELATING TO (*Continued*)—

(*a*) in the case of a sample taken at any time before the 1st day of January, 1924, not more than 200,000 bacteria per cubic centimetre; and

(*b*) in the case of a sample being taken at any time after the year 1923 not more than 100,000 bacteria per cubic centimetre.

(6) Until the 1st day of January, 1924, the requirements contained in paragraphs (1) and (2) of these conditions shall be deemed to be satisfied if the milk is treated not more than once by a suitable heating process and immediately cooled to a temperature of not more than 55° Fahrenheit.

J. D. M.

MILK, RECENT IMPROVEMENT IN THE PRODUCTION AND DISTRIBUTION OF—It is probably true to say that the milk industry in England has been revolutionized within the last sixteen years, and that its development has been particularly rapid during the past ten years. This change is very largely due to the fact that extensive studies of the proper methods of producing and carrying milk have been carried out by those who are working within the industry, and who are, therefore, in a position to bring their knowledge to its service. Formerly, such work had been carried out by a very limited number of representatives of the Public Health Authorities, of whom Delepine was a shining example, and little work was done by those who represented agriculture or the dairying industry, and thus such work as that of Delepine never became part of the conduct of the milk trade. In fact, the industry thought that the problems of the keeping and carriage of milk concerned the Public Health Authorities, and it was not realized that the industry was dependent for its living upon the purity of its supplies, and that, therefore, the persons most concerned in studying that subject were those who were directly interested in the progress of the whole milk trade, which represents at least 50 per cent. of the milk produced in this country.

The steps by which the present position has been attained may be worthy of consideration.

Work of the Ministry of Agriculture and the Milk Industry—In the year 1912 the Ministry of Agriculture and Fisheries and the Development Commissioners founded a research institute to study the problems of the milk and dairying industry. One of the earliest of the problems that was undertaken by its staff was a very thorough investigation of the problems involved in the keeping and carriage of milk. These studies revealed the following facts: that the successful production of milk depended, first, to a much greater extent upon the quality of the labour than upon the buildings, and, therefore, the stress which was sometimes laid on expensive and special equipment was not really necessary for success; secondly, on the absolute cleanliness of the worker and the cow; thirdly, on efficient sterilization of all implements and utensils; and, fourthly, on efficient cooling of the milk.

There has been considerable difficulty in securing the adoption of

MILK, RECENT IMPROVEMENT (*Continued*)—

the last of these necessities, as the requisite plant was not available to the farmer at a price that he felt he could pay, but as time has gone on, and its need has been felt more and more, these plants are now being produced at a very much lower cost than was formerly the case, and are being adopted by the members of the industry in increasing numbers throughout the country.

This work made it possible for the Ministry of Agriculture and Fisheries to inaugurate a great campaign with the object of improving the general level of the cleanliness of the milk in England and Wales. That this might be accomplished several steps were taken, laboratories were set up at the different provincial centres throughout the country at which studies of the cleanliness of the milk which was being produced might be undertaken, and instructors were appointed in the counties to advise and help those farmers who wished to enter for clean milk competitions and thus improve their supplies. The first competition of this character was held in 1920, when the prize was offered by Howard's Dairies in Essex, and was won by Captain Skelton. In 1921 two counties, and in 1922 and 1923 three counties, had initiated competitions. In 1924 this number had risen to nineteen; in 1926 there were forty, and thirty-four in 1929. This number represents some 950 dairy farmers scattered throughout England and Wales who were all competing together, usually for a period of six months, to see which of them could produce the cleanest milk.

In the year 1927, for the first time, an inter-county competition was held and was won by the county of Cornwall. The prize was given to that county which attained the highest standard in its county competition. That these competitions are resulting in the production of a milk of greater cleanliness than was formerly the case is undoubtedly true, and progress has been much assisted by the Universities, the Agricultural Colleges, the County Councils throughout the country, and certain societies of agriculturists, such as the Royal Agricultural Society of England, the British Dairy Farmers' Association, the National Farmers' Union, and others.

Recently the milk industry as a whole has taken an increasing interest in the promotion of better supplies. This has been shown in at least three different ways. For a number of years classes for dairymen have been held at the Chelsea Polytechnic in London. They were the only classes of the kind in the country, and were attended by constantly increasing numbers of members of the trade, at whose request an application was made to the London County Council that they should be extended, with the result that this winter three additional classes are being held in London and one in Birmingham. There is little doubt that before long these classes will extend throughout the country. It is hoped that the day may come when no one will be permitted to undertake the distribution of whole milk who has not given evidence that he has knowledge of the proper methods of handling it.

Not only has the industry demonstrated its interest in the increase of knowledge among its members, but it has realized that the farmer

MILK, RECENT IMPROVEMENT (*Continued*)—

ought to receive an improved price for a better quality, including cleanliness. The Midland Counties Dairy Company, Birmingham, were the pioneers in this movement for the payment of an additional sum for an improved quality of ordinary milk. The work was begun in 1922, when the company opened a bacteriological laboratory and proceeded on the following lines: first, regular examinations were made of the farmers' milk as it came into the depôt; second, advice was given on the farm when the necessity arose; and, third, an extra price was paid to a certain proportion of the farmers supplying the cleanest milk. By these means very great improvements have been effected, for whereas in 1922 less than 4 per cent. of the farmers were able to deliver milk of which the average bacteriological count was less than 10,000, in 1929 the percentage had risen to 60. In 1922 54 per cent. of the farmers were sending in milk with a count of less than 200,000, and in 1929 89 per cent. were able to do this successfully. These improvements have not only been beneficial to the firm concerned, but have represented financial advantage to the farmers.

The Midland Counties Dairy Company has now gone a stage further in this work by dividing up the workers in the depôt itself into groups which are responsible for special parts of the work, conducting regular bacteriological examinations of the condition of all the plant which is in use, and paying a bonus in accordance with the quality of the results obtained.

Work of a similar character is now being carried out by approximately thirty other milk dealers in different parts of the country. Most of these firms adopt a bonus scheme for a certain number of those farmers who send in milk within a certain standard of cleanliness. This method of payment has proved satisfactory when the work is in its early stages, since at that time many of the farmers do not attain to the standard, but as time goes on and improvements are effected the method does not appear to be just to many of them. A few firms, therefore, are adopting a method by which all farmers who attain to a certain standard shall receive this bonus; thus, by degrees, recognition of the extra financial value of ordinary milk of approved cleanliness is being attained within the industry.

In addition to the work which has been described, the industry has set up the National Milk Publicity Council in order to impress upon the consumer the value of milk as a foodstuff. Their efforts have met with great success, and it is estimated that, at the present time, there are some 500,000 school children in England and Wales receiving an extra ration of milk every day. In addition, business firms are beginning to encourage their workers to drink more milk. The work of this Council has been much assisted by the general improvement in the supplies of milk, and by the experiments upon the feeding value of milk which have been conducted under the auspices of the Ministr of Health.

Work of the Ministry of Health—The Ministry of Health is responsible for administering the Acts which govern the sale of milk

MILK, RECENT IMPROVEMENT (*Continued*)—

It is not necessary here to consider all the details of these Acts, but rather the way in which they have been used in order to promote progress.

Since one of the most important events within the industry occurred during the War, when the sale of milk was under Government control and the price was fixed, it seems fitting that they should be mentioned here, for it was then found that a certain number of producers of milk, as, for example, Mr. W. Buckley, were already producing a special type of milk from herds which did not react to the tuberculin test, and on their own initiative had created a market for this milk. It was clear that if these producers were compelled to accept the price of ordinary milk for their product, it would not be possible for them to carry on, and therefore they were granted special licences for the sale of their milk and permitted to make an extra charge for it. This event occurred in the year 1918, and was the first official recognition of the fact that milk of greater purity than the ordinary was worthy of an extra price. When the War was over the Milk and Dairies Consolidation Act of 1915, which had been in abeyance during the War, was made effective, and an Amending Act dealing with milk sold under special designations was passed in 1922. Thus the policy of official recognition of the value of milk of high quality to the nation was confirmed and extended. (See Milk, Provisions relating to the Production and Sale of.)

Under these Acts the Ministry of Health, acting in collaboration with the Ministry of Agriculture and Fisheries, exercises control over the possible sources of disease which may be communicated to milk at the time of its production or subsequent handling, and the conditions under which it shall be produced and handled are laid down. In addition, licences can be obtained for the production and sale of milk under the special designations which are set out in Table I. given on p. 821. From this it appears that two kinds of milk from herds which do not react to the tuberculin test, and one from herds which are subject to regular veterinary inspection, may be produced and sold in the raw state. Provision is also made for the sale of two grades of pasteurized milk. In addition to these many other types of milk—as, for example, ordinary farm milk either fresh, pasteurized, sterilized, condensed or dried milk, etc.—are all available, thus the consumer has a very wide range of different types of milk of steadily improving quality from which to choose.

The progress of the industry owes much to the way in which the Ministry of Health has utilized its very wide powers. The 1915 Milk Act required a variety of alterations in the methods of producing and handling milk, some of which were not easy of immediate accomplishment. The Ministry, therefore, postponed the duty of completing some of these alterations for a sufficiently long period to minimize the difficulties which the industry had to overcome. Not only was this done, but numerous classes for sanitary inspectors who are concerned in the administration of the Milk Act have also been instituted at agricultural centres. This work has established a much closer

MILK, RECENT IMPROVEMENT (*Continued*)—

relationship between those who administer the Acts and those who produce and handle milk, than was formerly the case. It was the Ministry of Health also which, with the aid of the Medical Research Council, carried out the extensive experiment on the value of the addition of milk to the diet of children of school age in Dr. Barnardo's Home, which has been of great assistance to the industry. This experiment has since been followed up by two others in Scotland and Northern Ireland, and a fourth is in progress now towards the costs of which the Empire Marketing Board has given considerable assistance.

TABLE I.

HERDS.

Designation.	*Tuberculin tested at Regular Intervals.*	*Veterinary inspected at Various Intervals.*	*Maximum Standard Plate Count.*	*Coliform Bacilli not Present in.*	*Other Conditions.*
Certified	Yes	Yes	30,000	$\frac{1}{10}$ c.c.	Bottled on farm, the name of farm, day of production, and word " Certified " on each bottle cap.
Grade " A " tuberculin tested	Yes	Yes	200,000	$\frac{1}{100}$ c.c.	Delivered to consumers in (*a*) the bottles or the sealed containers received from the farm; (*b*) suitable containers of not less than 2 gallons capacity; (*c*) bottles with the name of the dealer by whom the milk was bottled, the address of the licensed bottling establishment, the day of production, and the words " Grade 'A' T.T." or " Grade 'A' " on each bottle cap.
Grade " A "	No	Yes	200,000	$\frac{1}{100}$ c.c.	

PASTEURIZED MILK.

Grade " A " Pasteurized.—Grade " A " milk that after pasteurization as required by the Minister of Health contains not more than 30,000 bacilli per cubic centimetre and no coliform bacillus in $\frac{1}{10}$ c.c. All other conditions as required for Grade " A " milk.

Pasteurized.—Any milk that after pasteurization as required by the Minister of Health contains not more than 100,000 bacilli per cubic centimetre. No requirement for bottling.

MILK, RECENT IMPROVEMENT (*Continued*)—

The following references may be of assistance to those who wish to go further into these matters: "Studies concerning the Handling of Milk," 3rd edit., 1929, Research Monograph No. 1, Ministry of Agriculture and Fisheries; "Instruction in Clean Milk Production," *J. Min. Agric.*, vol. xxxvi., No. 11, February, 1930; Annual Report of the Chief Medical Officer of the Ministry of Health for the year 1929.

R. S. W.

MILK, TAINTS IN—Milk, and dairy products made therefrom, are not infrequently tainted owing to the fact that the cows producing the milk have consumed certain plants containing principles which are readily passed into the milk. Perhaps the most common of these tainting species are the field garlics and wild onion, the presence of which in grass land may render the milk of cows quite unfit for consumption.

Among plants which may be most likely to cause taints in this way may be mentioned the following:

Penny Cress (*Thlaspi arvense* L.).
Hedge Mustard (*Alliaria officinalis* Andrz.).
Corn Chamomile (*Anthemis arvensis* L.).
Wild Chamomile (*Matricaria chamomilla* L.).
Butterwort (*Pinguicula vulgaris* L.).
Garlics (*Allium* sp.).
Tansy (*Tanacetum vulgare* L.).
Cow Wheat (*Melampyrum arvense* L.).

Still other plants which have a harmful influence in connection with milk production are the following:

Buttercups (*Ranunculus* spp.).
Mercury (*Mercurialis perennis* L. and *M. annua* L.).
Oaks (acorns) (*Quercus* spp.).
Marsh Marigold (*Caltha palustris* L.).
Meadow Saffron (*Colchicum autumnale* L.).
Horsetails (*Equisetum* spp.).
Hemlock (*Conium maculatum* L.).

H. C. L.

MILLET—For feeding value see Feeding Stuffs and Poultry Nutrition.

MILLING OFFALS—For composition and feeding value see Foods and Feeding; Feeding Stuffs; and Poultry Nutrition. For Manurial value see Feeding Stuffs.

MINERAL METABOLISM—See Metabolism, Mineral.

MINERALS, REQUIREMENTS OF FARM ANIMALS—See Food and Feeding; Metabolism, Mineral, and Poultry, Nutrition.

MINT—See Market Gardening.

MOLASSES—For composition and feeding values see Feeding Stuffs; also Sugar-Beet, and Sugar-Cane.

MOLE DRAINING—A cheap and effective method of draining heavy land. (See Draining.)

MONKEY NUT—For composition and feeding value see Feeding Stuffs.

MOULD FURROW—The mould or hint-end furrow is the last furrow made in ploughing. When the last two furrow slices of the ridges have been laid over, the bottom of the open furrow between them is very wide. The plough goes along the middle of this wide open furrow and lays over a small triangular furrow slice on one side; it returns in the same furrow and lays another triangular furrow slice on the other side, up against, and covering, the lowest end of the last ridge furrow slices. This hollows out the ground into a mould furrow and forms a drain for surface water. (See Ploughing.)

MURIATE—An old name for "chloride," given in the eighteenth century in accordance with the view then held that hydrochloric (muriatic) acid was an oxy-acid of a supposed element called "murion" or "murium." The name has been abandoned in scientific literature for upwards of a hundred years, but still persists in commerce to a slight extent.

MURIATE OF AMMONIA (Ammonium Chloride)—See Fertilizers.

MUSHROOMS—The cultivated mushrooms are of the same species as that which grows wild in meadows and pastures (*Agaricus campestris*), the only difference being that those in cultivation are varieties differing from one another by the colour and general appearance of the skin, the size, flavour, and weight. The three varieties most generally known are the white, the yellow, and the grey. The white, while being of the finest quality and most in demand, is neither so vigorous nor so productive as the yellow, and the latter is, moreover, larger, heavier, and less liable to damage than the white. The grey variety has an excellent flavour, but its darker colour probably accounts for its being less in demand.

Granted adequate supplies of fresh, straw-littered stable manure, from well-fed healthy horses, the chief secret of successful cultivation is the type of spawn used for spawning the beds. It has long been recognized that it was necessary frequently to resort to "virgin" spawn for the making of spawn cakes, but owing to the uncertain origin of the "virgin" spawn, the varieties produced from it were often unsuitable. The difficulty was really due to the fact that the spores which gave rise to the "virgin" spawn appeared to germinate only in nature, but a big advance was made when, as a result of scientific investigation, spawn was obtained direct from spores by a new and special technique. Today, highly productive virgin spawn is obtainable in the form of dry cakes or tablets, and with its aid skilled growers are able to raise very profitable crops. The chief source of this spawn is France. Mushroom beds can be made up in caves, sheds, and glasshouses, and, in the warmer weather, in the open air, but quarries, caves, and glasshouses, provided there is a good circulation of fresh air, are probably the best, as the temperature can be kept more uniform. The temperature should never go above 75° nor below 48° F., the best average lying between 54° and 59° F. The beds are spawned when their temperature has fallen to and remains about 78° or 80° F.

MUSHROOMS (*Continued*)—

at 3 ins. depth. The spawn cakes are revived before use by exposing them, after moistening, to a moderately warm and humid atmosphere for a few days. Small pieces of spawn are inserted into the beds from 1½ to 2 ins. deep and about 10 or 12 ins. apart each way. After a few days the beds should be " cased" or " soiled" with sifted light, sandy loam, slightly moist to make the casing compact and firm, to which a little calcareous material, such as chalk, old lime, or old plaster, has been added. The final covering of the beds should be several inches of straw litter to keep in the heat. The mushrooms will appear in from three to four weeks after casing, and production will extend from two to three months.

The fertility of the beds can be maintained by watering them, when on the dry side, with a mixture of liquid manure and saltpetre at a temperature of from 70° to 80° F.

Marketing—Mushrooms are marketed in wicker baskets and chips; to avoid bruising in transit, 6, 8, or at the most 12 lbs. per package are the most suitable weights.

The almost universal shortage and high price of stable manure has changed the whole outlook of commercial mushroom growing. The crop will pay best when the cost of the manure can largely be discounted, as where the beds are made up in market glasshouses in the winter months, the spent beds being used afterwards for mulching tomato borders or for enriching the soil.

Insect Pests include the fungus gnat (*Sciara præcox*), whose larvæ infest the mushrooms, and *mites* (*Tyroglyphus mycophagus*), which feed on the mycelium and embryo mushrooms. Springtails (*Achorutes armatus*) and wood lice also work destruction.

Diseases: *White Mould of Mushrooms* (*Mycogone perniciosa*)—This disease is accountable for much damage in mushroom houses, and is difficult to eradicate. The chief factor determining the time of appearance of the disease is the quantity of infection. With a heavy deposit of *Mycogone* spores the attack appears with the first mushrooms, while a lighter infection does not produce diseased specimens until later.

Sometimes the diseased mushrooms are normal in shape, but bear a dense, flocculent felt of mycelium externally on the stipe or the gills. At other times the mushrooms are greatly deformed, with a much enlarged stipe, whereas the pileus and gills are reduced in size. In extreme cases, this " sclerodermoid " form of diseased mushroom does not show any of the parasite externally. Once infected, the mushrooms quickly decompose owing to enzymic action by the parasite.

M. perniciosa, the parasitic fungus which causes this disease, may be introduced with the "spawn " used to inoculate the beds. Consequently, care should be taken to obtain " spawn " only from places where the parasite is known not to exist.

If only a small part of the mushroom bed is attacked, all diseased mushrooms should be removed and burnt, and the parts of the bed within a foot radius of the diseased mushrooms disinfected with 1·5 to 2 per cent. lysol or 2 per cent. formalin solution. Once a " house "

MUSHROOMS (*Continued*)—
is infected seriously, the compost should be removed and the interior disinfected with 2 per cent. formalin solution.

REFERENCES.—F. E. V. Smith, "Three Diseases of Cultivated Mushrooms," *Trans. Brit. Myc. Soc.*, vol. x., 1924; Edmund B. Lambert, "Studies on the Relation of Temperature to the Growth, Parasitism, Thermal Death Points, and Control of *Mycogone perniciosa*," *Phytopath.*, vol. xx., No. 1, Jan., 1930.

Gill Mildew of Mushrooms (*Cephalosporium lamellæcola*)—This disease is fairly widespread, but not very serious. The parasitic fungus causes a "mildewing" of the mushroom gills, accompanied by fasciation. The gills of the young affected mushrooms, in addition to the fasciations, have a mottled appearance which later changes to a uniform glaucous pink. In the later stages the gills become black with a fine web of mycelium covering them. The diseased mushrooms are quite edible unless they are kept for some time, when the parasite produces putrefaction of the gills. The parasite does not grow nor secrete enzymes so vigorously in the mushroom tissues as does the parasite *Mycogone* responsible for the "White Mould" disease, and consequently the damage done is small.

No means of controlling the disease have been found.

REFERENCE.—F. E. V. Smith, "Three Diseases of Cultivated Mushrooms," *Trans. Brit. Myc. Soc.*, vol. x., p. 81, 1924. H. H. S.

MUSTARD—The cultivation of this crop, to the extent of about 25,000 acres annually, is confined almost entirely to England. Two species of mustard are grown for seed: brown or black mustard (*Brassica nigra* Koch, *Sinapis nigra* L.) and white mustard (*B. alba* Rabenh., *Sinapis alba* L.).

BROWN OR BLACK MUSTARD, an annual British species, in many respects resembling charlock, is cultivated for the oil contained in its seed, or for the flour which is used as a table condiment.

The plant is 2 ft. or more in height; the stem is branched and covered with well-developed hairs; the lower leaves are rough and lyrate and light green in colour; the upper leaves are lanceolate and smooth. The flowers are yellow, and the seeds are contained in smooth pods, ½ to 1 in. in length, and extending into a small beak. (See Brassicæ.)

The oval, brownish-red seeds turn grey if allowed to become wet and heated. They contain normally about 22 per cent. of oil, which can be extracted by pressure, leaving a cake behind which was formerly utilized as a feeding stuff, but is now only used as a manure. Mustard is usually grown on contract, the seed of brown mustard being rather more valuable than that of the white form, and contract prices are consequently somewhat higher.

Soils—The mustard-growing districts are situated in the east of England, the most suitable soils being the deep alluvial silts of South Lincolnshire, Norfolk, Cambridgeshire, and Huntingdonshire. Such soils are naturally fertile and are highly farmed for potatoes, which is

MUSTARD (*Continued*)—

the most important crop in these localities. Unsuccessful attempts have been made to grow brown mustard on light soils.

Sowing and After-Cultivation—Brown mustard is grown, as a rule, after a potato crop, and is then followed by wheat. It will succeed after a cereal if suitably manured, and is one of the safest crops to take on newly broken up grass land. Brown mustard, like white mustard, sheds its seeds readily, but is much more persistent, and may become a troublesome "weed" in succeeding crops; for this reason landlords do not encourage its cultivation. Seedlings from shed seed, however, may be controlled by adopting a rotation of potatoes, mustard, clover, wheat; the clover being sown under the mustard. If, on the other hand, the mustard land is kept well stirred after harvest most of the shed seeds will germinate, and can be then destroyed, and the more normal procedure of wheat after mustard may be followed.

Brown mustard is sown on a fine, well worked but firm seed bed, from March to mid-April, or even as early as the last week of February in favourable weather.

The seed is best sown in rows from 15 to 20 ins. apart. The weights should be taken off the drill before drilling to avoid sowing the seed too deeply. Three or four lbs. of seed per acre are used. When the rows can be seen from end to end it is usual to flat-roll, which is followed by light harrows worked along the rows when the plants are about 4 ins. high. It is considered best to thin the plants out to 10- to 12-in. spaces, but, on account of the labour involved, the more usual practice on 15- to 18-in. rows is to run a wheat horse hoe across the rows. Some form of thinning is undoubtedly desirable, although in practice mechanical thinning is often omitted when the rows are wider than 18 ins. Horse-hoeing between the rows is done in the early stages of growth.

Manuring—Since mustard is most commonly grown after a potato crop, in which as much as 15 cwts. per acre of artificials may be used, further manuring is unnecessary. After a cereal, however, the crop will respond to a dressing of farmyard manure, or a mixture of artificials with a high phosphate content. Three to four cwts. of superphosphate per acre is frequently the only manure required on good land after a cereal crop.

Harvesting—Sown in March, brown mustard is ready for harvest in August. It is cut just as the pods turn brown; if cut too early the seed is shrivelled; if cut too late many may shed out. Brown mustard is usually cut by hand, although thin crops may be harvested by binder. Cutting by hand is nearly always done by piece-work, the harvesters using a hook or sickle and tying the sheaves by hand. The sheaves are not stooked like corn, but laid on the stubble, which is left long intentionally so as to hold the crop off the ground.

In good weather carting may be possible two days after cutting; under less favourable conditions, turning by hand may be necessary, for mustard for seed must be brought into the stack dry. Great care

MUSTARD (*Continued*)—

must be exercised in carting and stacking to avoid the seed being shelled out. The waggons should be lined with sheets, and the ground where the waggons and elevator stand should also be sheeted, and the accumulation from the sheets emptied over the stack from time to time. The stack bottom should also be covered with a cloth made by joining old sacks.

The common threshing tackle with smaller sieves will thresh and clean the crop satisfactorily, but care should be taken to set the beaters correctly to avoid splitting the seed, which should not be threshed within six weeks of stacking. In some districts, specially lined low carts are used for carting.

Yield—On good land 5 to 6 sacks per acre (2 cwts. per sack) may be expected, although it is possible to grow 10 sacks to the acre under exceptionally suitable conditions. The straw yield is negligible, for it is useless for feeding, although the seed pods are sometimes fed to horses and cattle.

WHITE MUSTARD—This annual plant is grown chiefly for sheep feed, or as a green manuring. It grows stronger and taller than brown mustard; its stems are hispid and distinctly furrowed. The leaves are pinnatifid, the lobed segments being rough. The flowers are pale yellow, and the pods short and rough with a beak curved like a dagger. White mustard seeds are larger than those of brown mustard and whitish-yellow in colour.

Cultivation for Seed—White mustard can be grown for seed on poorer soils than can brown mustard, and does not shed its seed so readily. Its cultivation for seed is similar to that practised for raising seed from brown mustard. The time of sowing, however, is later—April or May being sufficiently early, for white mustard is a very quick-growing plant. It is drilled in rows 12 to 18 ins. apart, and therefore rather narrower than brown mustard, and the seed rate, 7 to 12 lbs. per acre, is distinctly heavier. It is thinned by cross horse-hoeing. Harvesting methods are the same, except that it is usually impossible to use the binder in cutting white mustard.

The yield of seed is similar to that of brown mustard. Both sorts of mustard are susceptible to frost, but white mustard is not so readily attacked by the mustard beetle, which is a pest causing serious damage to mustard crops. Methods of control, however, are known, and are effectively practised.

F. R.

Insect Pest: Mustard Beetle—Mustard seed growers often suffer serious losses from attacks of the small blue beetles known as the Mustard beetles. They also attack other plants of the cabbage family, such as cabbages, cress grown for seed, turnips, and even watercress. They are widely distributed throughout Europe. The chief culprit is *Phædon cochleariæ*, but three other allied species are sometimes found. The beetles pass the winter in mustard stubble or straw, but may be found in other sheltered places, such as dyke sides and hedge bottoms. In the spring they leave their winter quarters and feed on the young

MUSTARD (*Continued*)—

mustard plants. They lay eggs on the underside of the leaves, and from these, small grubs, at first yellow, and later yellow with black spots, hatch out. These feed for two or three weeks on the mustard leaves and then, when about ¼ in. long, pass into the soil and pupate. In about ten days another generation of beetles crawl up from the soil.

In the course of the season, two (or possibly more) generations may be found, but the most serious damage is done shortly after the flowering period, when the grubs and beetles eat the leaves. When these are finished, the depredators feed on the bark of the flowering stem, and may in this way ruin the crop. The damage to other crops is very similar.

Control—The beetles usually take up their winter quarters by the middle of October; if after this date the mustard stubble can be burnt, many of the beetles will be destroyed. The cleaning and burning of dyke sides and hedge bottoms will also get rid of large numbers. It must also be remembered that a number of beetles hibernate in the mustard straw.

Spraying the crop with poisons such as Paris green and lead arsenate so that the grubs and beetles are killed when they eat the leaves has given satisfactory results.

Paris green gives better results than lead arsenate, and should be used as follows:

Paris green (powder)	¼ lb.
Hydrated lime	½ lb.
Calcium caseinate	1½ lbs.
Water	40 gallons.

The spray should be put on with a potato sprayer at the rate of about 100 gallons per acre, and as much of the spray as possible should be applied to the undersides of the leaves. The spraying should aim at killing as many as possible of the beetles and grubs of the first generation.

The first spraying should be done when the mustard is about a foot high; a second spraying may be done about a fortnight or three weeks later. A third spraying may be necessary, and finally, in the case of a severe attack, it is possible to spray shortly before flowering with good results, although a certain amount of injury may be done to the plants by the sprayer as it moves through them.

Good results have been obtained by Mr. E. E. Edwards of Kirton by dusting the plants with the following:

Paris green (powder)	1 lb.
Hydrated lime	24 lbs.

which is sufficient for 1 acre. Dusting with a poison of this kind, however, is rather dangerous.

F. R. P.

NARCISSUS—See Bulb Growing.

NETT ENERGY VALUES—In this country it is still largely the custom to compute rations for animals by means of the starch equivalent system (*q.v.*) introduced by Kellner, in so far as any scientific basis

NETT ENERGY VALUES (*Continued*)—

for this is adopted at all. The other system, with which this article deals, was introduced by Armsby and Fries in 1915 (*J. Agric. Res.*, iii., 435), and is becoming more and more used, both here and on the Continent, for scientific purposes, while in America it is universally employed. From the scientific viewpoint it has the advantage of giving the energy requirement of animals for various purposes in terms of energy units. This, however, is often offset in its application to practice by the unfamiliarity of the terms it employs. It is more rigorous quantitatively, but as has been pointed out by Halnan (*J. Agric. Sci.*, vii., 136, 1915), this may be less of a blessing than appears.

The train of thought leading up to the conception of nett energy values is as follows: The *total energy* content of unit quantity of any feeding stuff is quite unknown, and we must therefore select a datum level of energy content and find what is contained above that level. The level chosen is the energy content of the water, carbon dioxide, nitric oxide, and sulphur dioxide to which the feeding stuff may be converted by complete oxidation. The two latter of these occur only in small quantities in the products of combustion. The energy content above this datum is measurable by making a complete combustion of the feeding stuff in a bomb calorimeter in an atmosphere of compressed oxygen; it is known as the *gross energy*. This cannot all be used by the animal which ingests it, a portion always passes away as chemical potential energy in the excreta (including marsh gas, CH_4, etc.), and when the amount so wasted is subtracted from the gross energy we are left with what is called the *metabolizable energy* (or gross digestible energy). Kellner's work, leading to his starch equivalent system, clearly indicated that even this energy was not *all* available to the animal for purposes of maintenance or production, since there is another form of excretion which has not been taken account of above—that is, the invisible excretion of energy itself in the form of heat, either sensible or latent in water vapour. When this amount is finally deducted we arrive at the so-called *nett energy* of the quantity of feeding stuff considered, and this is its value to the animal for maintenance, fat production, meat production, etc. That the nett energy content for these various purposes may differ is clear, as the heat loss may be different in each case and, indeed, almost certainly is so. (See Foods and Feeding.)

One may express the matter succinctly in the form of an equation thus:

Energy in fodder - (Energy in fæces + Energy in urine + Energy in methane + Energy lost directly as heat) = Energy available for maintenance and production.

Møllgaard points out ("Om Grundtrækkene af Malkekvægets Ernæringslære," Copenhagen, p. 8, 1929) that in effect Kellner measures the right and Armsby the left hand side of this equation. So that it is but natural that they should arrive at parallel results.

It is perhaps desirable to indicate *en passant* that, strictly speaking, small additions should be made to the quantities in the brackets for the heat required to heat up the food and water to the temperature of the animal, for the heat of solution of urine solids, energy excreted

NETT ENERGY VALUES (*Continued*)—

in intestinal gases other than methane, etc. It is also interesting to speculate as to whether the heat required for solution of urine solids comes out of that which would otherwise go to waste, or out of that which would otherwise go to production. The amounts involved are small, however, and their possible effect not much larger than the errors involved in the experiments—"*non ragionam di lor ma guarda e passa.*"

Practically all direct measurements of heat production with different feeding stuffs have been made upon cattle. The original experiments of Armsby and Fries (*l.c.*) were entirely so, and failed to show any definite difference as between submaintenance and supermaintenance rations. The following example taken from Armsby ("Nutrition of Farm Animals," New York, p. 272, 1917), in which two submaintenance rations were fed, will serve to illustrate both the theory and method of computation from the experimental results:

The results were obtained from experiments on a steer and the figures were:

	Dry Matter of Hay Eaten. Lbs.	*Metabolizable Energy.* Cals.	*Heat Produced.* Cals.	*Gain of Energy.* Cals.
Period 4	10·21	9,544	9,812	-268
Period 3	6·17	5,768	8,064	-2,296
Difference	4·04	3,776	1,748	2,028
Difference per pound dry matter of hay ..	—	935	433	502

From the figures it is clear that the increase of the ration by 4·04 lbs. of hay caused the daily loss of energy from the body to fall from 2,296 Calories to 268 Calories, thus *preventing the loss of* 2,028 *Calories*; in other words, each pound added saved the animal the loss of 502 Calories, but each pound of hay actually contained 935 Calories of metabolizable energy, of which clearly only 502 were used for maintaining the steer, the other 433 being lost as heat. Thus, the nett energy value of timothy hay deduced from this experiment would be 50·2 therms per 100 lbs. dry matter in the hay, one therm being equal to 1,000 kg. calories (see Calories). Nett energy values are sometimes given in this form, in other cases as therms per 100 lbs. of hay, meal, etc. The former is better, as the water content is more or less variable and therefore introduces another uncertainty.

The nett energy values of concentrates cannot be determined as above for cattle, but the principle of the method is identical. It is customary to feed a basal ration of hay and add the concentrate to this; *e.g.*, if in the above example in period 4, instead of adding 4·04 lbs. of hay to the 6·17 lbs. given in period 3, a suitable quantity, say 2 lbs., of some concentrate had been added, the resulting figures would have given the nett energy value of the concentrate when given with hay.

Space does not permit of a discussion of the corrections to observed values necessary to arrive at these final figures, or of the analysis undertaken by Armsby and Fries of the sources of the increment of

NETT ENERGY VALUES (*Continued*)—

heat production; for this the original paper, to which a reference has been given, must be consulted.

Let us now illustrate briefly how a ration may be computed from the nett energy values of its components. We will take a ration for maintenance of a 100 lbs. large white pig in a small sty at 62° F. Such a pig requires about $\frac{1}{3}$ lb. of digestible protein daily,* and this means that the energy requirement must be supplied by mixed ingredients to secure it without waste of money on expensive fodders. According to certain results published from this laboratory with all reserve, as the number of animals experimented upon was not great enough to justify a categorical statement, such a pig may be expected to require about 2,100 Calories of nett energy daily. Now, taking a rough figure, this amount will be contained in about 2 lbs. of meal, since on an average just over 100 therms nett energy/100 lbs. may be reckoned for normal pig mixtures. Two pounds of the ordinary 65:25:10 contains less protein than $\frac{1}{3}$ lb., but it is approximately supplied by a mixture of 55 per cent. barley meal, 20 per cent. sharps, 15 per cent. soya bean meal, and 10 per cent. fish meal; let these therefore be chosen as the constituents, and we have:

	Therms Nett Energy.
55 lbs. barley meal at 106·08 therms/100 lbs. contains	58·34
20 lbs. sharps at 103·73 therms/100 lbs. contains	20·75
15 lbs. soya-bean meal at 108·42 therms/100 lbs. contains ..	16·26
10 lbs. fish meal at 97·76 therms/100 lbs.† contains ..	9·78
∴ 100 lbs. mixture contains	105·13

105·13 therms = 105,130 Calories, whence if 105,130 Calories is contained by 100 lbs. of the mixture, 2,100 Calories is contained by $\frac{100 \times 2{,}100}{105{,}130}$ lbs. of the mixture = 2·00 lbs., which is the maintenance ration; it is mere chance that it happens for the weight of pig and mixture chosen to come to *exactly* the rough figure taken for adjustment of protein requirement.

Recently E. B. Forbes, who succeeded Armsby at the Pennsylvania State College, has put forward a number of results obtained there which go to show that nett energy values for maintenance may be appreciably higher on submaintenance than on supermaintenance rations. The following figures are averages for the two steers he used; the full figures are published in *J. Agric. Res.*, xxxvii., 253, 1928:

	Nett Energy per Cent. of Metabolizable Energy:	
	Between Fasting and Maintenance.	*Between Maintenance and 2 × Maintenance.*
Alfalfa hay	69·2	32·0
Corn meal	88·1	73·7

Except in the fasting experiments (at 17·2° C.) no particulars appear to be given as to the temperature of experimentation. Forbes seems

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* Armsby based on Kellner.

† Estimated fr. value for blood meal in ratio of starch equivalents from Wood ("Rations for Livestock," 5th edit., 1927).

NETT ENERGY VALUES (*Continued*)—

disposed to explain these results by assuming a specific dynamic effect of body nutrients katabolized, a view which the writer has criticized in another place (see Calorimetry, Animal). He would prefer to consider that under the circumstances of Forbes' experiments it may be that the thermic energy content of rations below maintenance level may be used, at least in part, to prevent body material being wasted for the purpose of maintaining the temperature of the animal above that of its surroundings. Another possible explanation is suggested in the final paragraph of this article. Armsby and Fries, as the result of a large number of experiments, considered that they had failed to find " . . . any distinct evidence of a greater relative increase of heat production on heavy, as compared with light, feed, or on supermaintenance as compared with submaintenance rations . . ." (*J. Agric. Res.*, iii., 476, 1915). Deighton (*J. Agric. Sci.*, xix., 160 *et seq.*, 1929) has investigated the metabolism of pigs at various stages of fasting, and comes to conclusions identical with those of Forbes to this extent, that the nett energy values of feeding stuffs at maintenance are almost certainly not applicable below that point. He is inclined to the idea that changes in nutritive plane are in no wise distinguishable from those due to thermic energy of ingested food; but the whole matter must be considered as still *sub judice*. From the purely theoretical standpoint the findings of R. Bonnet (" Métabolisme energétique et Alimentation Consommation de luxe et Action dynamique spécifique," Gap, 1929) merit careful consideration.

In the matter of nett energy for growth little is certainly known. For swine a beginning might perhaps be made by starting from the determination of fasting katabolism of young pigs at various ages determined at Cambridge (see Deighton, " The Basal Metabolism of a Growing Pig," *Proc. Roy. Soc.*, B95, 340, 1923; and "A Study of the Metabolism of Two Breeds of Pig," *J. Agric. Sci.*, xix., 140, 1929). Even then the question remains whether the fasting katabolism is the proper point from which to compute nett energy values as much in the young pig as in older animals.

Armsby has attempted to deduce nett energy values for the performance of mechanical work on the assumption that the nett energy requirement is equal to the body energy katabolized in doing the work. We must remember, however, in this connection the very various circumstances which may disturb the proportionality between these two factors; as Møllgaard so succinctly puts it ("Om Grundtrækkene af Malkekvægets Ernæringslære," Copenhagen, p. 19, 1929): "In mechanical work the effect is certainly not determined by the amount of feed, but the consumption of nutrients is determined by the amount of work done. Meanwhile, as is well known, proportionality is only maintained between the mechanical work done and the consumption of nutrients provided that efficiency remains constant; and as this varies with the kind of work, its amount and the time rate at which it is done, to say nothing of the effect of state of training of the animal and the composition of the ration, the direct determination of nett energy values is in this case practically impossible to carry through " (tr. T. D.).

NETT ENERGY VALUES (*Continued*)—

Møllgaard has occupied himself for the past fifteen years with the question of nett energy values for milk production. He finds that these vary with both the size of the ration and the point in the lactation at which the investigation is carried out, and is so rigorously controlled by the latter factor, that even very considerable increases in the ration are quite unable to drive the milk production above the maximum level corresponding to the point in the lactation curve at which the animal may be at the moment. He has determined the following conditions as necessary for the minimum metabolism with production of 1 kilogram of milk, viz.:

(1) The animal must be near the N_2 minimum.

(2) The animal must be in N_2 balance. (See Balance, Carbon and Nitrogen.)

(3) The animal must be in energy balance.

(4) The animal must maintain the milk yield constant for the whole of the fairly long experiment.

As the result of many and prolonged experiments, Møllgaard has come to the conclusion that the best method of rationing for milk production is to supply over and above what is required for other purposes an amount of fodder equal to 837 Calories of nett energy computed for *fattening* for every 1,000 Calories to be taken off as *energy in milk*. This latter is a linear function of the fat content. The further stipulation is made that one-fifth part of the nett energy supplied for this purpose shall be in the form of protein. For further particulars his work, already quoted, should be consulted.

Energy requirements of pregnant cows for milk production have not, so far as the writer is aware, been investigated. Møllgaard recommends the addition of 1,000 Cals. to the above figure during the last half of the gestation period.

In general, the crucial question in all this field is as to whether or not the fasting katabolism of an animal is the true measure of its maintenance requirement in terms of nett energy. Armsby and Fries assumed this to be so, but it has never been definitely proved. Forbes' results already quoted are *susceptible* of explanation on the assumption of a higher maintenance requirement of nett energy at higher planes of nutrition, since the extra nett energy demanded for maintenance metabolism over fasting katabolism is by supposition entirely degraded to heat, as it is employed in preventing the katabolism of body nutrients which, though not actually katabolized in fasting requirements, would be so if the animal did not get on to a more economical plane of nutrition. Thus, the observed thermic energy is increased, and the nett energy correspondingly reduced under supermaintenance conditions. The writer does not necessarily subscribe to this view, but it is put forward rather to indicate the point to which he conceives that attention must be directed in order that the small outstanding difference between theory and practice may be reconciled. Tables of nett energy values will be found at the end of Armsby's "Nutrition of Farm Animals," New York, 1917.

T. D.

NEW ZEALAND, Agriculture of—See Agriculture.

NITRATE OF LIME—See Fertilizers.

NITRATE OF SODA—See Fertilizers.

NITRIFICATION—Nitrification—the oxidation of ammonia to nitrate by soil—was made use of for producing saltpetre for gunpowder, in nitre beds, at a period long before the importance of the process for plant growth in ordinary soil was realized. It was, further, the first important change to be ascribed to the activity of micro-organisms, rather than to definitely chemical action. The biological nature of the change was first established by Schloesing and Müntz (*Comptes Rend.*, vol. lxxxiv., p. 301, 1877); it is worth noting that the primary study of these investigators was sewage, for nitrification as a means of preventing the accumulation of ammonia is as important there as in the soil, and much of our later knowledge of nitrifying organisms has come from similar studies. Warington (*J. Chem. Soc.*, vol. xxxiii., p. 44, 1878) at once saw the application of their results to the production of nitrate in soils, and confirmed and extended their work in this direction. Although he was unable to isolate the organism in pure culture, he examined its behaviour in solution culture, as well as in soils, towards various disinfectants, light, and other changes in environment. It was left to Winogradski, using inorganic culture media, to isolate and describe bacteria capable of producing nitrite and nitrate from ammonia (S. Winogradski, *Ann. Inst. Past.*, vol. iv., p. 213, 1890). These organisms, however, especially those producing nitrite, appear to be relatively uncommon in soil, and restricted to a very narrow range of conditions in culture; some quite recent work has shown that numbers of other nitrite-producing bacteria exist in soil (and in sewage), and are capable of flourishing over a much wider range of conditions (D. W. Cutler, *Nature*, vol. cxxv., p. 168, 1930). Warington may actually have had cultures of these organisms, without convincing himself or others of it.

The Process of Nitrification—It was soon found (Warington, *loc. cit.*) that nitrite as well as ammonia could be oxidized to nitrate by the soil organisms, and Winogradski showed that the process of nitrification actually proceeds in two stages:

(1) The production of nitrite from ammonia;
(2) The production of nitrate from the nitrite;

each requiring a distinct type of organism. The bacteria concerned effect the oxidations simply to gain energy, just as other organisms oxidize carbon compounds; practically the whole of the nitrogen originally present as ammonia appears eventually as nitrate, instead of being built up into protoplasm by the bacteria—in this sense, the nitrite and nitrate may be regarded as waste products similar to carbon dioxide. (Under artificial conditions certain nitrite-producing bacteria have been observed to absorb nitrite at a later stage, but this does not appear to take place appreciably in the soil.)

NITRIFICATION (*Continued*)—

(1) *Nitrite-forming Bacteria*—The characteristic bacterium identified by Winogradski as responsible for the first stage is *Nitrosomonas*, and a number of closely related organisms are recognized, including *Nitrosococcus*, from the New World. There are in addition the new forms noted by Cutler, which appear to be quite distinct morphologically and physiologically. It is not proposed here to go into the methods of isolating and growing nitrifying bacteria (see, for example, Waksman, " Principles of Soil Microbiology," London, 1927); it should be noted, however, that in pure culture *Nitrosomonas* is very sensitive to the presence of organic matter, and requires the addition of some alkaline earth carbonate to preserve an alkaline reaction of the medium; whereas, in the soil, nitrification proceeds readily in the presence of organic matter, even in soluble forms, and persists even in acid soils. The newly described nitrite producers show a similar indifference to acid reaction or to soluble organic materials.

(2) *Nitrate-forming Bacteria*—Winogradski described only one organism capable of oxidizing nitrite to nitrate—*Nitrobacter*—and no other distinct forms have since been isolated. It may be obtained from cultures of nitrifying bacteria in the later stages of nitrification, when the ammonia has disappeared and nitrate is being actively formed; it lies dormant in the presence of ammonia (free ammonia, such as would be present in cultures with an alkaline reaction), so that nitrate production does not begin in these cultures until the ammonia has been oxidized to nitrite. In soils, however, where the ammonia is mostly held in the exchangeable form by the colloids, nitrate production is not inhibited by ammonia (at least in moderate amounts), so that the two stages go on simultaneously.

In ordinary soils the action of *Nitrobacter* is so vigorous that no more than a trace of nitrite can be detected, even when a considerable amount of ammonia is being oxidized: the velocity of the second change, nitrate production, is so much greater than that of the first, nitrite production, that nitrite has no chance to accumulate. Accumulation of nitrite only occurs under conditions unfavourable to *Nitrobacter*, as in soils so strongly alkaline that free ammonia is liberated.

The Conditions of Nitrification in Soils—Although existing knowledge of the nitrifying organisms is far from complete, this does not affect the results of the work that has been done on the influence of changing conditions on nitrification in soils. Changes in environment may be classed for convenience in two groups, according as the factor studied is physical or chemical:

Physical—As in all biological processes, *temperature* has a considerable influence on the rate of nitrification, although the available information is not very comprehensive. Schloesing and Müntz observed appreciable activity at 5° C., and while 45° C. was injurious, it required about 55° C. to stop nitrification completely; the optimum temperature is generally given as about 37° C. In some recent work in the field, nitrification proceeded through the winter, at temperatures

NITRIFICATION (*Continued*)—

of 5° C. and lower. Although nitrification is stopped in frozen soils, it goes on with increased vigour on thawing.

Moisture Content likewise affects the rate of nitrification, particularly at the extremes. The optimum value is not sharply defined, varying probably with the water-holding capacity of the soil; air drying checks nitrification, although on remoistening it proceeds more vigorously than before, and too great a moisture content finally stops nitrification through waterlogging and the production of anaerobic conditions.

Reaction—The reaction necessary for the growth of cultures of most nitrifying organisms is slightly on the alkaline side of neutrality, and the range is much more limited than that over which nitrification can proceed in the soil. The limiting reaction here is affected by such factors as organic matter or salt content, but nitrification has been shown to proceed between pH 3·7 and pH 8·8 (C. Olsen, *C. R. Lab. Carlsberg*, vol. xvii (8), 1928), with an optimum at pH 8. Nitrification is, however, considerably retarded under acid conditions (see also Hall, Miller, and Gimingham, *Proc. Roy. Soc.*, B, vol. lxxx., p. 196, 1908), and in acid soils it responds favourably to liming.

Chemical or Nutritional Factors—The division between these and the preceding group is necessarily arbitrary—for example, the influence of reaction is bound up with that of lime, while aeration, although in a sense physical, is actually important from the nutritional point of view, of oxygen supply.

Air—It was found, very early in the history of nitrification experiments, that increased aeration, as by shaking the soil or leading air over a thin layer, greatly accelerated nitrate production. In surface soils in the field this factor is unlikely to be limited, except by waterlogging, although its importance is shown by the limited occurrence of nitrifiers and nitrification in the subsoil (Hall, *et al., loc. cit.*). In the laboratory, however, adequate aeration is very necessary in any studies of nitrification; not only the actual production of nitrate, but even the preliminary stages, such as the ammonification of urea, are retarded by insufficient aeration. In pot experiments also, especially in deep pots, aeration may be defective and nitrification consequently hindered.

Ammonia—Given adequate aeration, the most important nutritional factor is the supply of ammonia. Where a salt of ammonia is added, or a nitrogenous fertilizer supplying ammonia, if other conditions are suitable there will be an initially high concentration of ammonia in the soil which will be reduced gradually by nitrification, and the rate of nitrification will be controlled largely by the physical factors already discussed. But in ordinary soils, or after the addition of slowly available organic materials, the rate of ammonification is less than that of nitrification, so that the concentration of ammonia will remain low, and the production of nitrate will be limited actually by the rate of production of ammonia. This raises the question of the sources of nitrifiable nitrogen, which will be discussed in a separate section.

Lime—The importance of lime in nitrification has already been

NITRIFICATION (*Continued*)—

mentioned, and its relation to the effect of reaction. It is not certain, indeed, that much lime is necessary, purely from a nutritional point of view, to supply calcium for the cells; its chief importance is probably to neutralize the acid residues of the other half of the molecule after the ammonia has been nitrified, and to combine with the nitric acid itself. In other words, it prevents the development of physiological acidity. (See Lime and Liming.)

Other Elements and Salts.—Toxic effects have been demonstrated for a considerable variety of these under artificial conditions, or in alkali soils, while certain have been said to stimulate nitrification at high dilutions. Their importance in ordinary soils is probably not great. Similarly, in ordinary field soils applications of fertilizers seem to have had little direct effect on nitrification, although under conditions of, *e.g.*, extreme phosphorus deficiency, some response to phosphatic fertilizers might be expected.

Organic Matter—Whereas Winogradski's nitrifying bacteria in culture were exceedingly sensitive to small quantities of soluble organic substances, this is not observed in soil. Apart from the presence in any case of the rather resistant humus materials, additions of soluble organic matter have been observed actually to stimulate nitrification in soils, unless carried to excess (*e.g.*, Stevens and Withers, *Centr. Bakt.*, II., vol. xxvii., p. 169, 1910). In sewage, also, organic matter is rather beneficial than deleterious.

Poisonous Organic Substances—The influence of soil disinfectants, including partial sterilization agents, has frequently been examined. Another substance which is exceedingly toxic to nitrification is dicyanodiamide (Cowie, *J. Agric. Sci.*, vol. ix., p. 113, 1919), although in view of the small proportion that would be added to the soil in ordinary fertilizer applications (of cyanamide or its mixtures), the importance of its action in the field has probably been exaggerated. It may be observed that recent work has shown that cyanamide is even more toxic to nitrifiers than is dicyanodiamide, but its action is less marked as it disappears much more rapidly in the soil.

Sources of Nitrifiable Nitrogen—Apart from that added in fertilizers or as traces in rainwater, the ammonia upon which nitrifiers depend for their source of energy is derived from the decomposition of plant and animal residues. While all these contain nitrogen, its amount and availability vary greatly: whereas animal excreta are exceedingly rich in available nitrogen, and most other animal residues contain a fair proportion of nitrogen which is relatively rapidly available, the majority of plant materials are low in nitrogen, and what there is becomes available only slowly. Indeed, in the early stages of the decomposition of materials poor in nitrogen, the organisms responsible may even require available nitrogen for their own nourishment, and remove it from their surroundings. In this way, if unrotted material such as straw is ploughed into the soil shortly before a crop is sown, a competition is set up between micro-organisms and plants that may be quite harmful to the latter.

NITRIFICATION (*Continued*)—

Which of the two processes, the liberation of available nitrogen or its absorption, preponderates during the microbiological decomposition of an organic material is largely controlled by the ratio between its carbon and nitrogen contents. If the carbon/nitrogen ratio is low (the proportion of nitrogen is high), then some nitrogen will remain over after the breaking down of the complex molecules containing carbon, and this nitrogen will appear before long as ammonia. Indeed, with a material such as blood, ammonia may be produced so rapidly and reach such a concentration as to be injurious to plants. But if the carbon/nitrogen ratio is high, the material will not decompose readily without the addition of further nitrogen available to the micro-organisms (as in the manufacture of artificial farmyard manure), and this nitrogen may be locked up by them for a considerable period. The actual value of the carbon/nitrogen ratio above which there is no liberation of available nitrogen varies with the material undergoing decomposition and with the reaction of the soil; Jensen found (*J. Agric. Sci.*, vol. xix., p. 71, 1929) that in soil with an alkaline reaction there was no appreciable nitrification of material with a carbon/nitrogen ratio about 25, while in an acid soil the limiting ratio was lower—about 15 (the difference was attributed to the predominance of fungi in the latter decomposition: they synthesized more protoplasm and stored up more nitrogen than did bacteria).

The ammonia which results from the decomposition of suitable organic materials is the final stage of a series of changes, accompanied by the breaking down of the complex molecules of proteins and amino-acids. It is also produced rapidly and directly from urea—the simplest form to which animals can reduce nitrogenous material. This change is formulated simply as a hydrolysis, effected either by bacteria or by an enzyme (urease) that may be produced by bacteria or found in plant tissues: $(NH_2)_2CO + 2H_2O = (NH_4)_2CO_3$. In these ways ammonia is steadily being produced in the soil, although it rarely accumulates to any appreciable extent because of its further conversion to nitrate.

Nitrification in the Field—As has already been indicated, certain of the conditions affecting nitrification that are important in the laboratory are of less importance in the field so far as normal, fertile soils are concerned. In these soils, aeration, as a result of diffusion and mass movements of air, is sufficiently good not to need consideration as a factor; similarly, moisture supply will probably be adequate, except in unusually dry periods; and temperature, even in midwinter, is not so low in temperate climates as to inhibit or seriously retard nitrification. Reaction, in the form of extreme acidity, such as may be observed in moorland soils or in the neighbourhood of industrial towns, may definitely hinder nitrification and allow the accumulation of ammonia; but a moderate degree of acidity is unlikely to affect nitrification appreciably.

On the whole it may be said that the production of nitrate in most soils—given a sufficient supply of nitrifiable material—proceeds at such a rate as not to require especial consideration in relation to

NITRIFICATION (*Continued*)—

fertility. The most likely disturbing factor is waterlogging, whether this occurs naturally as the result of poor drainage or is practised as a definite feature of cultivation, notably with the rice crop. In a waterlogged soil ammonia may accumulate rapidly (Subrahmanyan, *J. Agric. Sci.*, vol. xvii., p. 429, 1927), but there is no nitrification—possibly a slight initial loss of nitrate—and no change in nitrite. Nitrification becomes very vigorous again on partial drying.

In the field, a factor much more important than the rate of production of nitrate is the rate of removal. The plant takes what it can, but it is competing with other agencies, such as micro-organisms decomposing high-carbon organic materials, and, particularly in humid or temperate climates, with leaching as the result of excess rainfall. The importance of leaching in relation to nitrate supply was recognized by the earliest workers, and the quantitative relationships between seasonal rainfall and growth that have been worked out in recent years serve to emphasize it. Examining the relationship between rainfall and yield of wheat on the differently manured plots of Broadbalk, Fisher observed (*Phil. Trans. Roy. Soc.*, B, vol. ccxiii., p. 89, 1924-25) that the predominant feature of the comparison was the influence of excessive rain in removing soluble nitrates, which effect marked and overwhelmed all others. Further, the bad effect of winter rainfall was particularly marked on plots that received a nitrogenous fertilizer, part of which was applied in the autumn. It is clear that nitrate applied to uncropped soil in autumn would be washed out by winter rains, and recent measurements in the field have shown that in England winter applications of ammonia are likewise nitrified and washed out by spring; even when growing plants are in the soil—such as winter wheat, or grass land—leaching may remove so much of the added nitrogen during the relatively dormant period of the plant's growth as to make early spring application more economical than application in early winter. Another aspect of the question of leaching is this, that after heavy winter rains the nitrate content of the soil may be so low as to set up severe nitrogen deficiency, with stunted growth and yellowing of the leaves; but even a small application of nitrogenous fertilizer in early spring will counteract this and carry the crop through the difficult period. (See Lysimeters, and Wheat.)

In the more arid parts of the world, leaching is naturally less important as a factor in nitrate supply. Nitrates from natural sources may actually accumulate in the soil, reaching so high a concentration that nitrogenous fertilizers produce no response; if there is a response to added nitrogen it may be as great in the year following application as in the first season.

The other factor responsible for the removal of nitrate from soils differs from leaching in that the nitrate is not lost to the soil completely, but is rendered temporarily unavailable. It has already been remarked that the organisms decomposing material of a high carbon/nitrogen ratio require nitrate for their nutrition, and the addition of such material to soils may be followed by a serious temporary loss in fertility or check to growth simply as a result of this competition.

NITRIFICATION (*Continued*)—

As instances, the addition of fresh straw, chaff, or sawdust, or of unrotted manure containing a high proportion of litter, may be quoted; also, the use of molasses, sugar-beet tops, or sugar-cane trash. These materials have their uses, but they should be either rotted down before adding to the soil (by supplying nitrogen and moisture), or else incorporated sufficiently long before a crop for decomposition to be completed. This is best done in autumn, for a spring crop: the nitrate then locked up is protected from winter leaching, and largely liberated in the spring.

Green manuring may be considered in this connection: if the crop is poor in nitrogen, it may be followed by a temporary decrease in fertility immediately after ploughing in, but such a crop turned in in the autumn may be expected to be quite beneficial in the spring; indeed, it may even prevent some of the loss of nitrates by winter leaching. On the other hand, if a high-nitrogen crop is ploughed in (or grazed off) in the autumn the residues may decompose so rapidly that most of the potentially available nitrogen is lost during the winter, and the good effect of the crop is lost. (See Green Manuring.)

The Importance of Nitrification in Plant Nutrition—While it was once thought that plants took up their nitrogen as ammonia, since the middle of last century it has been assumed that nitrate is their source of nitrogen, and that nitrification is necessary before the nitrogen in the soil is available to plants. There is, however, a growing body of evidence that many plants may use ammonia also, or may even prefer it to nitrate (Prianischnikov, *Biochem. Zeits.*, vol. ccvii., p. 341, 1929). It has even been suggested that nitrification should be regarded as a safety device to prevent the accumulation of toxic quantities of ammonia in soil rather than as an essential preliminary to plant nutrition. This view may be as extreme as the other, but there is no doubt that certain plants, such as rice, may use or even prefer ammonia as their natural source of nitrogen, and it seems quite likely that many other plants, finding both ammonia and nitrate present in the soil, may take what they can get of either. The fact that the ammonia is mostly in the insoluble condition, held by base exchange, need be no obstacle to this view, for potash held by the soil in the same way is readily available to plants.

The relative advantages of the two forms of nitrogen seem to depend partly on reaction, nitrate being better under acid and ammonia better under neutral conditions. Differences in the extent to which various species can assimilate ammonia or nitrate almost certainly exist, and may be responsible, in combination with factors such as smothering and acid tolerance, for the differential response of meadow plants to nitrogenous fertilizers. The repression of clover and encouragement of grasses by sulphate of ammonia, for example, is too marked after even a single application to be attributed simply to its influence on the reaction of the soil. This question of the form in which plants can assimilate their nitrogen has come under reinvestigation too recently for definite statements to be possible. It is evident

NITRIFICATION (*Continued*)—

that problems of nitrogen fertilization will take on a new aspect if ammonia, as well as nitrate, is a source of nitrogen for plants, especially if their relative value varies with different plants and with the reaction of the soil.

H. L. R.

NITROGEN (Symbol N (often Az in French works); atomic weight 14·008; atomic number 7)—An inert or almost inert gas of which the air is composed as to four-fifths of its volume. Its compounds, amongst which we may enumerate nitrates, ammonium salts, cyanides, all proteins (*q.v.*), etc., are of the highest importance in the biological scheme of things. The element itself is colourless, tasteless, and odourless, and almost insoluble in water; beyond this it calls for no notice here.

Fixation of Atmospheric—Several processes have been developed in the past quarter-century for the fixation of the nitrogen in the air, thus assuring the supply of nitrogenous manures for future generations. Calcium cyanamide or nitrolim is made by heating limestone and carbon in the electric furnace; this yields calcium carbide, which unites with the nitrogen of the air to form 'cyanamide,' $CaCN_2$. This process is carried out at Odda, Rjukan, Alby, and Niagara. In the soil the cyanamide slowly decomposes to calcium carbonate and ammonia, or the decomposition may be effected at once with superheated steam.

In the Haber process carried out by the Badische company, nitrogen and hydrogen are caused to combine directly at a high temperature and pressure. The reaction $N_2+3H_2 \rightarrow 2NH_3$ goes to the extent of 40 per cent. when the temperature is 550° C. and the pressure 1,000 atmospheres. The reaction is exothermic, but goes too slowly at ordinary temperatures. The ammonia formed is either dissolved in sulphuric acid to form ammonium sulphate, or else is oxidized to nitrate. Atmospheric nitrogen is also obtained in the form of nitrate of lime, $Ca(NO_3)_2$, by burning air at 3,000° to 3,500° C., producing nitric oxide which is immediately oxidized by excess oxygen to nitrogen peroxide, which in the presence of moisture acts as a mixture of nitrous and nitric anhydride, and yields nitrate of lime when absorbed by slaked lime. (See Fertilizers.)

In this connection the process of recovery of nitrogen from the air which goes on continually in the fields by means of the nodules on the roots of leguminous crops, the bacteria in which provide by this means a satisfactory supply of nitrogen for the well-being of their host, must not be overlooked.

NORTHERN IRELAND, Agriculture of—See Agriculture.

NUTS—Botanically speaking only those fruits possessing a hard, dry pericarp which does not split open at maturity are termed nuts, but in popular language, and more especially by commercial usage, any fruit possessing a permanent hard outer layer or shell is loosely termed a nut. An example of a true nut is found in the hazel nut, but on the other hand walnuts and coconuts, both commercial nuts,

NUTS (*Continued*)—
are not true nuts in the botanical sense of the term, the pericarp in both instances consisting of a soft outer layer, the exocarp, and an inner hard shell, the endocarp, the latter, after the former has been shed, imparting the nut-like appearance to the fruit. The pea nut (ground nut) of commerce is simply the hardened pod of a leguminous plant which has the habit of burying its pods in the ground, hence the name of "ground nut." All the so-called "nuts," however, possess one other feature in common besides the hard outer covering or shell. This feature is that the endosperms of the seeds within the shells are unusually large, and are packed with large quantities of reserve material such as oils, fats, starches, and proteids. Because of this feature, the "nut"-bearing plants throughout the world have been considerably exploited by man and occupy a place of high economic importance.

The coconut (*Cocos nucifera*) and the palm-oil nut (*Elæïs guineinsis*), for example, furnish the vegetable oils which are largely employed in the manufacture of margarine and soap, respectively.

Also, many of the nuts are of an edible nature, and are sold for human consumption, and are employed in the confectionery trade.

In the tropics, the coconut, ground nut, palm-oil nut, and the brazil nut are cultivated for the sake of their crops. In the temperate zones the chief nut-bearing plants are the sweet chestnut, the walnut, the almond, and several forms of the hazel nut.

In the British Isles enormous quantities of walnuts and chestnuts are consumed every year, the bulk of the supplies coming from Spain, Italy, and France.

The only nuts of importance grown in the British Isles are the cob nuts and filberts (improved forms of *Corylus Avellana*), and the walnut (*Juglans regia*).

Cob Nuts—The cultivation of cob nuts, a form of filbert, is confined almost exclusively to Kent, where it is estimated that there are about 1,500 acres of the variety known as the **Kentish Cob,** which was introduced to cultivation about 1830 by a Mr. Lambert, hence the name of **Lambert's Filbert** by which it is sometimes known. The localized nature of the cob-nut industry is rather difficult to explain, but its development as a special Kentish crop may be due partly to the fact that conditions of soil and climate particularly favourable to the industry exist in that county, and partly to the fact that the crop calls for skilful management, particularly in pruning the trees. The Kentish cob-nut plantations possess all the attributes of the unique, and although the expert knowledge relative to their management may be handed down from generation to generation, there is actually little opportunity for this experienced practice to spread to other areas.

The cob nut appears to thrive particularly well on the soils of the Hythe Beds of the Lower Greensand formation, and most of the famous nut plantations of Kent are associated with this formation. Even the shallower and stonier areas of this formation suit the nut trees quite well, from which it may be deduced that the ideal soil for this crop must be of an open, porous nature, and that rich, deep soils are not so suitable in that they force the trees into an excessive

NUTS (*Continued*)—

growth of wood. The low rainfall of Kent is undoubtedly another favourable factor, as the yield of nuts depends considerably on the formation of well-ripened fruiting wood.

The Kentish cob nut, in common with other members of the group, is propagated chiefly by layering, *i.e.*, bending down and covering with soil the young shoots which spring from the stools. These shoots when rooted are severed from the parent stock, and are planted out in nursery rows, where the foundation of the future training system is laid. The importance of well-trained plants for setting out in their permanent quarters cannot be over-stressed, and the young trees must remain in the nursery until they possess a head of five or six good, evenly balanced, leaders on a stem of from 12 to 18 ins. As a rule this can be obtained by judicious use of the knife in a period of two years in the nursery bed, so that the young cob-nut tree is usually three, or sometimes four, years old when planted in its final site.

Properly trained cob-nut trees will ultimately possess a spread of about 6 ft. from the trunks, and as space will be necessary to enable the pickers and pruners to get all round the trees, they should never be planted closer than 15 ft. (193 trees to the acre), and on very favourable nut land 20 ft. (108 trees to the acre) is advisable.

Pruning is the most important part of cob-nut cultivation, as without skilful treatment with the knife the trees not only grow out of shape and become unproductive, but the quality of the nuts decreases considerably. As has already been indicated, the training of the tree is commenced in the nursery and must be continued, without cessation, throughout the tree's life. In Kent, the general practice is to train the trees into a basin shape with the whole of the centres open and free from growth. To start the trees on the right lines, wooden hoops are sometimes employed, but a skilful pruner can usually manage without this aid. It is, however, a long and laborious process, and a cob-nut tree trained on this principle may easily be from thirty to forty years before it is fully developed. Commencing with the rudimentary framework of the tree taken from the nursery, the desired shape is gradually built up by cutting back each year's growth to a few inches of stout wood, in order to induce strength. As this goes on the primary branches may be allowed to break in order to fill up the space. The lateral growths, of which an abundance will be produced each season, must be spurred back to two or three buds. These spurs will produce most of the fruit, and to strengthen and encourage their formation many growers go over the trees during August and practise a system of summer pruning. Instead of cutting the lateral shoots completely away, however, they are merely broken with the hand and allowed to hang. This "brutting" of the cob-nut trees, as it is called, has a considerable effect on the cropping powers of the trees, and is considered to be well worth the expense of carrying it out.

Another aspect of the pruning of nuts is that the trees, being monœcious in character, must be furnished with a plentiful supply of catkins (male flowers) if good crops are to result. The trees blossom

NUTS (*Continued*)—

during February, when the small scarlet-tipped female flowers, embedded in a sheath of scales, are very difficult to see. By deferring the pruning of the trees until the end of February or early March, especially in seasons when catkins are not plentiful, the fertilization of the female flowers is ensured. A wise pruner will always contrive to leave a sprinkling of catkins on the tree after he has completed the season's pruning, to provide pollen for any late-developed female flowers. All suckers and other sappy growths which spring up from the base and out of the centres of the trees should be removed each year. When these suckers spring from the trunk of the tree they should be broken off with a sharp twisting motion. Cutting them off will only cause more suckers to appear from the same place.

The land beneath cob-nut trees should always be cultivated, as the trees do not like grass. In fully developed plantations this is usually carried out by hand-forking in the winter followed by hand-hoeing at intervals during the summer. The question of manuring the trees should receive very careful consideration, as cob nuts may quite easily be over-treated with manure, and over-manured trees are quite as unfruitful as under-manured trees. Slow-acting organic manures such as shoddy, feathers, and fur waste are often better for nuts than farmyard manure, which may force the trees into much rank growth.

Many Kent growers apply from 20 to 30 cwts. of good shoddy every year, with a dressing of lime or basic slag every three years.

When carefully managed the cob-nut plantations are very profitable and yields of 1 ton of nuts per acre are often obtained. An average of from 12 to 15 cwts. would, however, be regarded as a satisfactory yield. There is no imported nut to equal in quality and flavour the Kentish cob, and each season's crop is always readily disposed of at good prices. The nuts are gathered about mid-September just before the husks commence to turn yellow. When picked at this stage the nuts adhere to their husks, and after careful drying, they are despatched to market in this condition. It is true to say that many people fail at cob-nut growing because they omit to give proper consideration to the several details which count for success.

Walnut—It must be admitted that, so far as Great Britain is concerned, the walnut has not received much attention from the point of view of the yield of nuts, but is more often planted as a shade, ornamental, or timber tree, the crop of nuts being regarded as a fortuitous occurrence which possesses a cash value.

In southern Europe and in California the walnut crop is of considerable economic importance, and in the latter country there are reported to be 130,000 acres of walnut-bearing groves.

In this connection it must be pointed out that the walnut trees of the British Isles are all of seedling origin, whereas modern methods of walnut cultivation require that the trees should be raised by grafting or budding processes as in the case of other fruit trees, and it is certain that such trees respond to good treatment and careful cultivation.

NUTS (*Continued*)—

The development of the home walnut industry has no doubt been held up by the fact that the ordinary methods of outdoor grafting were found to give unsatisfactory results, and it was not until the East Malling Research Station took up the investigation of the subject that it was found that more satisfactory results could be obtained by carrying out the grafting processes in heated glasshouses.

The advantage of grafting for walnuts, of course, lies chiefly in the fact that, instead of having to reckon with a great number of varieties which would naturally arise from any batch of seedling trees, desirable varieties possessing good cropping powers and size and quality of nut may be propagated vegetatively to give reliable trees. An additional and important advantage is that grafted trees commence to bear crops much sooner than seedling trees. All the trees composing the famous walnut groves of California have been raised in this way, besides a considerable proportion of the trees of southern European countries.

Research work into walnut cultivation will no doubt be continued in Great Britain, and further valuable information may be anticipated. Where soils and climatic conditions are favourable farmers might well plant walnut trees on their holdings, as without allowing them to interfere with the ordinary cropping arrangements of the farm there are usually odd sites, not to mention boundary fences and hedgerows, where trees could be planted. The walnut is also especially suitable for enclosed park lands, and owners of private parks should find it to their interest to plant them.

The walnut thrives best in deep, sandy loams, but calcareous loams, provided they are not cold and wet, will also suit the trees. Clay loams underlaid by clay are not so suitable, and in such soils the trees make very little headway.

The grafted walnut trees are propagated on the common seedling walnut (*Juglans regia*). In California the black walnut (*Juglans nigra*) is employed. Where crops of nuts are the primary consideration, such trees should always be planted, and on account of the work carried out at East Malling they should soon be readily obtainable.

Although walnuts are prone to suffer from frost damage to the blossoms in early spring, poor crops of nuts are sometimes due to faulty pollination. This does not turn on the problem of self-sterility mentioned in the article on apples, pears, cherries, and plums, but on the ascertained fact that in walnuts, which are monœcious plants, the pollen of the catkins (the male flowers) may mature either too late or too early for the effective fertilization of the pistil bearing or female flowers. The near presence of other walnut trees which may provide sufficient wind-borne pollen is therefore an important point in walnut growing.

Although tradition dictates that walnut trees are better for having their crops removed by being threshed with long poles, nothing could be farther from the truth. The trees should always be carefully treated, and the ripe nuts which fail to drop naturally should be shaken off by means of rubber-covered hooks fastened to long poles.

OATS—When the last Agricultural Census of Production of Great Britain was taken, in 1925, the area devoted to the oat crop was 3,115,669 acres, which were distributed in the four divisions of the Kingdom as follows:

England ..	..1,688,151	acres, equal to	54·0	per cent. of the total acreage
Wales ..	.. 179,460	,, ,,	5·7	,, ,, ,, ,,
Scotland ..	.. 925,995	,, ,,	29·7	,, ,, ,, ,,
Northern Ireland..	322,063	,, ,,	10·3	,, ,, ,, ,,

In the same year the areas under wheat and barley were 1,551,752 and 1,472,802 acres respectively; the oat crop thus occupies slightly over 50 per cent. of the total area devoted to cereals in Great Britain and Northern Ireland. In 1930 the acreages were:

England and Wales	1,773,000
Scotland	867,000
Northern Ireland	306,809
Total	2,946,809

a decrease of 169,000 acres on the 1925 figures.

The importance of the crop in the rural economy of the four countries is indicated more clearly, perhaps, by expressing the acreage of the three cereals as percentages of the tillage area, *i.e.*, of the areas actually under the plough. In 1925 these were:

	Wheat.	*Barley.*	*Oats.*
England and Wales	18.5	16·3	23·0
Scotland	2·8	8·9	53·7
Northern Ireland	0·6	0·4	55·2

Presented in this manner, the figures of acreage indicate the first broad lines of geographical distribution. Thus, the percentage of the tillage acreage devoted to oats in Scotland is 53·7, and in Northern Ireland 55, and these two areas together account for 40 per cent. of the total oat acreage. There is in both cases a predominance of oats over wheat and barley, and even in England, where there are large areas devoted to wheat and barley, the oat crop still maintains a priority of position on the acreage basis. In addition, it is characterized by a very general distribution, and there are no areas where its cultivation is as definitely limited as is the case with both wheat and barley.

Nevertheless, the density of cultivation increases in a North-Western direction, that is, towards districts characterized by a higher rainfall and generally lower temperatures than exist in the eastern and south-eastern districts. (See Fig. 16.)

Total Supplies.—The total quantity of oats available for consumption in the United Kingdom annually has shown a steady decrease for a number of years. In 1909 the supply available was 4 million tons, a quantity that by 1927 had contracted by 1½ million tons, a reduction of 37·5 per cent. During this period the home production fell from 3,133,900 to 2,239,750 tons, or by 28·5 per cent. Concurrently, the imports showed a fall from 891,800 to 295,350 tons, or by an amount equivalent to 67 per cent.

Thus, the proportion of imported to home-produced oats has fallen

OATS (*Continued*)—

from 22 per cent. in 1909 to 11·7 per cent. in 1927, or, conversely, the home production, which amounted to 78 per cent. of total supplies in 1909, was 88·3 per cent. in 1927.

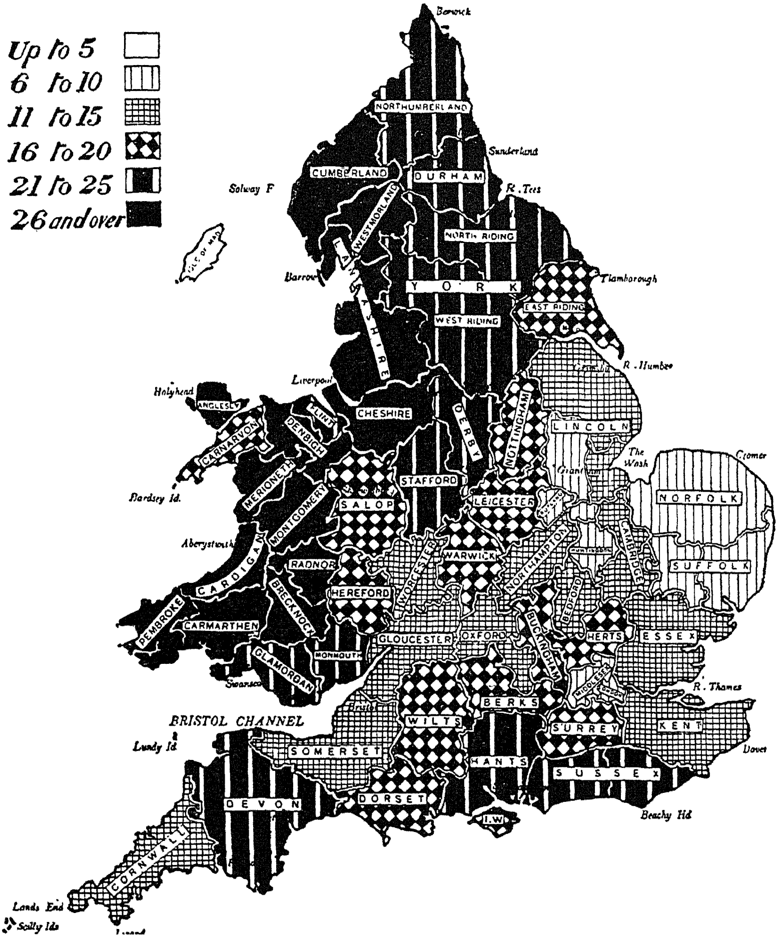

Fig. 16.—Showing the Number of Acres of Oats for 100 Acres of Arable Land in 1925.

(From " The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

The sources of the foreign supplies have also altered very materially since 1905, in which year 65 per cent. of the total imports came from Russia. At that time large quantities were received also from the United States and Germany, and smaller amounts from Canada and the Argen-

OATS (*Continued*)—

tine. By 1913 the quantity received from Russia had fallen considerably, and corresponding quantities from the Argentine, Germany, and Canada greatly increased. During the War the quantities received from the Argentine and the United States were largely augmented, but in 1925 Canada became an important source of supply of imported grain (*Min. Agric. and Fish.*, "Report on the Marketing of Wheat, Barley, and Oats in England and Wales," *Econ. Ser.* No. 18, 1928).

Some oats are now received from New Zealand also, and the supplies obtained from Imperial sources in 1923-27 represented two-fifths of the total imports.

The oats obtained from Canada and New Zealand, and to some extent from the United States, are bulks of varieties similar to those commonly grown in the British Isles, and their quality, although at times inferior to the home-grown grain, is of the same order. On the other hand, some of the supplies received from the United States, but more particularly from South America, are oats belonging to the species *Avena sterilis*, which are usually distinctly inferior in quality to derivatives of *Avena sativa*; nevertheless, in common with supplies of other cereals from drier countries, their "condition" gives them a slight commercial advantage, especially in seasons when it is difficult to harvest the home crop satisfactorily.

As in the case of home-grown barley, home-grown oats possess a quality superior to the generality of imported grain, the only commercial drawback at times being inferior "condition" and poor colour—both weather effects which do not necessarily detract from the intrinsic value of the grain for brewing and feeding respectively.

Utilization of the Crop—In addition to its priority of position in acreage in all parts of the United Kingdom, the oat crop is interesting by reason of the fact that at present not less than 85 per cent. of the annual total requirements is home-grown. Of the total home production, which amounts to approximately 2¼ million tons annually, a very large proportion is utilized for feeding on the farm, but, in addition, oatmeal accounts for 200,000 tons, and horses and poultry, other than those on the farm, for 850,000 and 125,000 tons respectively (*Min. Agric. and Fish.*, Econ. Ser., No. 18, 1928).

Geographical Distribution of the Home Crop—The geographical distribution briefly outlined above is evidence of the essentially moisture-loving nature of the oat plant as it is found in the United Kingdom. But although this may be regarded as a general tendency, there is a great deal of evidence of the adaptability of varieties to definite conditions of soil and climate within relatively small geographical boundaries. Thus, some varieties exhibit a preference for soils of a definite character, whether this is circumscribed by physical characters affecting the moisture-retaining capability, by fertility, or by the quantity of organic matter present. Others exhibit a marked relative superiority in warmer districts, while others, again, are cultivated with the greatest success in districts characterized by cooler conditions.

OATS (*Continued*)—

The number of varieties of oats now in use is very large, and the attention of those interested in the improvement of this, as of other crops, is gradually extending from the broad conception of soils suitable for oats as a whole to an attempt to determine the varieties best adapted to specific environments. This is in reality a recognition of the impossibility of changing soils fundamentally, and of the possibility of utilizing definite ecological characters of crop plants themselves.

The successful cultivation of oats in the British Isles is more closely related to an adequate rainfall, especially during the early periods of growth, than to special soil conditions. In parts of the country subject to heavy rainfall oats may be grown on essentially light soils, whilst in other parts, with a lower rainfall, they are frequently grown on soils approximating to typical wheat lands. Hooker, as a result of a statistical study of the effect of rainfall and temperature on the yield of crops, makes the following statement regarding oats: "Oats are similar to barley insomuch as they urgently require a cool summer. But they differ from barley in requiring rain in the spring; in fact, for the spring (season) the coefficient with rainfall (+0·70) is just above the summer coefficient with temperature (−0·69). Before harvest (twenty-fifth to thirty-second week), however, they would seem to like dry weather" (R. H. Hooker, "Correlation of the Weather and Crops," *J. Roy. Stat. Soc.*, vol. lxx., part 1, 1907).

Roberts, in summarizing the results of a study of the correlation of the yield of oats with meteorological observations in North Wales, states that "the oat plant is essentially a lover of cool, humid conditions in its later life periods. High temperatures, particularly if unaccompanied by precipitation in the later stages of ripening, may

if accompanied by high temperatures for the same period" (R. Alun. Roberts, *J. Agric. Sci.*, vol. xviii., 1928).

The wide and general distribution of the crop when viewed in conjunction with the character of the varieties used in different districts is striking proof of the importance of the extent of rainfall rather than of the character of soil in determining the extent of cultivation of oats in the British Isles.

Position in Farm Rotation—The position of oats in farm rotation differs essentially with the locality. In Scotland and in the north-western counties in England where there is a limited acreage of wheat and barley, oats succeed turnips, swedes, potatoes, or ley, or two crops of oats are taken in succession. In the corn-growing areas of east and south-eastern England, oats usually succeed wheat. They may on occasions follow barley, roots, or ley, but the general custom is for wheat to succeed ley or roots, and barley to follow roots; oats consequently follow a previous straw crop.

Whilst in the northern districts oats are usually spring sown, they may be either spring or autumn sown in southern areas, and for reasons

OATS (*Continued*)—

which will be described later there is a growing tendency to increase the area devoted to winter oats.

As an adequate supply of moisture during the vegetative development of the oat plant is such an important factor in the successful cultivation of the crop, the condition of the soil and its ability to conserve moisture are points deserving attention when deciding upon the position of the crop in a rotation.

Characters of varieties—Although there is an extraordinarily large number of oats in cultivation, those in use in the British Isles may all be grouped under the two species *Avena sativa* and *Avena strigosa*. Occasionally derivatives of the species *Avena sterilis* are met with, but so rarely that, as a whole, it does not merit attention here. The majority of the varieties of oats found in Australia. South Africa, the western states of U.S.A., in many parts of South America, North Africa, and along the Mediterranean littoral generally, however, are derivatives of this species.

The botanical characters differentiating the two species, *A. sativa* and *A. strigosa*, are confined mainly to differences in various parts of the florets of the spikelet. In all species of oats there are two glumes, or outer coverings, of a thin parchment-like nature which overlap slightly at their edges, and so function as protective coverings to the enclosed florets. Within the glumes there may be one, but more usually, two or three florets, each consisting of an ovary and three stamens, and each enveloped by an inner or ventral, and an outer or dorsal palea, which together constitute that portion of the oat grain commonly termed the "husk." The awn or "beard," when present, arises from the mid-vein of the dorsal palea.

The species *A. strigosa* is distinguished from *A. sativa* by the smaller size of grain, the prolongation of the outer palea into two long awn-like points, and by the presence of a strongly developed, geniculate awn, on all grains of the spikelet. Three sub-species have been described by Marquand ("Varieties of Oats in Cultivation," *Welsh Plant Breed. Stat., Series C*, No. 2, 1922), and in each sub-species the varieties are differentiated, *inter alia*, by the colour of the grain, which may be white, yellowish-white, grey, or black. The cultivation of varieties of *A. strigosa* as farm crops is confined entirely to high-lying land in Wales, to the north-west and to a few islands off the western coast of Scotland; in these localities varieties of *A. strigosa* succeed, while those of *A. sativa* are useless.

The straw of *A. strigosa* is usually long, fine, and succulent, and for this reason *A. strigosa* is sometimes sown with the small naked oat, **Piley** or **Pilcorn** (*A. nuda brevis*), in the hilly districts of south-west Ireland; in this case the greater portion of the crop is cut green and utilized as fodder for cows and other farm stock.

The species *A. sativa* includes the majority of varieties grown in the British Isles and in temperate zones throughout the world.

The inflorescence or head of oats in *A. sativa* is spreading, but the secondary branches bearing the grains may be pendulous, horizontal,

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or directed upwards. Those forms in which the branches are so far upwardly directed as to be adpressed to the rachis (or that portion of the straw bearing the head) are referred to a sub-species, *A. sativa orientalis*, or one-sided oats. In all respects, other than the direction of the spikelet-bearing branches, the inflorescence of *A. sativa orientalis* resembles that of *A. sativa*.

The varieties found under *A. sativa* may be grouped into several subdivisions according to characters, such as the habit of early growth, the amount of tillering, the colour, shape, and size of the grain, earliness and lateness in ripening, suitability for conditions of high and low rainfall, and ability to withstand winter conditions (H. Hunter, "Oats: Their Varieties and Characteristics," E. Benn, Ltd., London).

With such a relatively wide geographical distribution, it is only to be expected that some varieties possess a specialized use, but as a rule this is amenable to consideration on a geographical basis. In the northern districts and in districts of heavy rainfall, for instance, old-established varieties, such as **Potato, Sandy,** and **Hopetoun,** etc., which are characterized by high straw-yielding capacity associated with grain of high quality, still enjoy a considerable vogue. Throughout the more southerly districts the varieties in general use are **Abundance, Banner, Beseler's Prolific, Victory, Giant Eliza, Golden Rain,** and **Thousand Dollar**—all very similar botanically and all alike in exhibiting high grain-yielding capacity, associated with good standing straw, thus rendering them particularly suitable for soils of high fertility. A systematic attempt to determine the conditions of soil and climate most suitable to the best varieties must be regarded as one of the fundamental aims of improvement. An intensive attack on these lines is being made in Northern Ireland, where a small but very variable area offers excellent prospects of valuable results.

Under the conditions of low rainfall found in the east of England **Abundance** is perhaps the most suitable variety; in the north-west there is a partiality expressed for **Golden Rain,** which is slightly earlier in ripening; whilst in Wales, **Record** has proved a valuable variety.

On soils of moderate fertility, and specially in the south-western districts, **Black Tartary** and similar oats belonging to the subspecies *A. sativa orientalis* are grown extensively. The preference for such oats appears to be thoroughly justified, for in these localities they are relatively more productive than any of the varieties mentioned above.

Of varieties used for autumn sowing, there are only three meriting comment, viz., **Grey Winter, Black Winter,** and **Bountiful,** and in point of winter hardiness their order of value is as they are given.

The first, as its name indicates, is grey in colour, and the two others are black. **Marvellous,** a white-grained variety, was placed on the market as a winter variety in 1921, but it fails to survive except in mild winters, and its inclusion in the category of winter oats is not justified by the results of actual growth tests or by the possession of any of the attributes of true winter forms. (See "Trials of Spring Sown Oats, 1925-1929," *J.N.I.A.B.*, vol. ii., No. 3, 1930, and "Trials of Autumn Sown Oats, 1924-1928," *J.N.I.A.B.*, vol. ii., No. 2, 1929.)

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Rate of Seeding—The rate of seeding varies considerably with the variety, the environment, and to a small extent with the time of sowing. A normal seeding is from 12 to 14 stones per acre. High tillering varieties do not require to be sown so heavily as those characterized by a smaller tillering habit. In Northern Ireland the rate of seeding of spring oats is up to 20 stones per acre, and on very thin soils may even exceed this figure.

Large-seeded varieties do not usually possess high tillering propensities, consequently these sorts require a heavier seeding than those with a smaller grain.

There is a good deal of evidence that a uniform size of seed in any variety is a desirable feature, for field experiments show that the large seeds of a sample usually produce larger crops than the small ones. The effect of the more robust plants raised from the large seed of a sample is to check the growth of the plants raised from the smaller seed, and the yield of the latter is then inferior to that realized from the small seeds sown alone (W. M. Findlay, N.D.A., "The Size of Seed," *North Scot. Coll. Ag. Bull.*, No. 23, 1919).

Straw—In most parts of the country oaten straw is utilised for stock feeding, and in evaluating a variety the value of the straw must be viewed concurrently with that of the grain. The best feeding straws are those produced by varieties such as Potato, Sandy, etc., which, although inferior to many modern sorts in grain-yielding capacity, produce a fine, leafy, succulent fodder. This, in conjunction with a high quality of grain, justifies the retention of these and similar varieties in cultivation in districts to which they are known to be well adapted, and especially in those where bullock feeding is still a feature of farming practice.

Yield of Grain—The oat crop returns the lowest yield of grain of the three cereals, as the following table shows:

	Wheat.		*Barley.*		*Oats.*	
	1925.	1915-1924.	1925.	1915-1924.	1925.	1915-1924.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
England	18·2	17·2	15·4	14·7	15·1	13·7
Wales	15·1	15·0	13·2	13·2	11·2	11·1
Scotland	22·4	21·1	18·6	16·9	15·5	14·3
Northern Ireland ..	19·0	17·8	19·3	17·1	17·0	15·8

It will be observed that the highest yields of oats are obtained in Northern Ireland and the lowest in Wales, whilst the English returns are not much lower than those obtained in Scotland. In view of what has been stated regarding the difficulties attending the cultivation of oats in dry areas, the relatively high yields obtained in the eastern and north-eastern counties of England is somewhat anomalous.

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It must be pointed out accordingly that the two latter divisions include the Fen districts, which are extremely fertile and which, by reason of an organized system of land drainage capable of controlling the fall and intake of water, rarely suffer from the effects of drought.

The relatively low yields in Wales are probably due in part to the inferior grain-yielding capacity of the varieties of *A. strigosa* cultivated there.

Manurial Requirements—When oats are grown after another corn crop, or on soils of inferior fertility, it is advisable to apply some form of artificial manure. For this crop, as for both the other cereals, it is always safest to use a complete manure, *i.e.*, one containing the three manurial ingredients, nitrogen, phosphates, and potash, in some readily available form. There are occasions on which one of the three manures may be used alone, as, for instance, on a rich soil which is inclined to be late in ripening, when the use of forms of readily soluble phosphates is recommended, for they hasten ripening and assist in producing a well-filled grain. Again, when the applications of farmyard manure are necessarily limited, potash in some form is frequently remunerative. But unless there are strong reasons for the contrary, a mixture such as 1 cwt. of ammonium sulphate, 3 cwts. of superphosphate, and 3 cwts. of kainit per acre is found to be the safest and most remunerative artificial fertilizer. Nitrogenous manures applied alone, when there is not a sufficient supply of phosphates and potash in the soil, over-stimulate vegetative development, and the straw is then liable to be weak, and may " lodge " badly. The grain of crops receiving an excessive amount of nitrogen is also inclined to have a high percentage of husk.

Chemical Composition of Oat Grain—The grain of all cereals is characterized by a high carbohydrate content, but wheat, barley, and oats exhibit significant differences in the other constituents of the grain.

Kellner (" The Scientific Feeding of Animals," Duckworth, London) gives the following figures for the average composition of the three cereal grains:

	Moisture.	*Crude Protein.*	*Crude Fat.*	*N-Free Extract.*	*Crude Fibre.*	*Ash.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Wheat ..	13·4	12·1	1·9	69·0	1.9	1·7
Barley ..	14·3	9·4	2·1	67·8	3.9	2·5
Oats ..	13·3	10·3	4·8	58·2	10·3	3·1

But while wheat, when threshed, is divested of its enveloping paleæ, oats and barley both retain these coverings. In all varieties of barley, excepting certain naked forms, the paleæ are actually fused with the caryopsis, and cannot be readily separated therefrom. In

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oats, on the other hand, the caryopsis may be separated from the enveloping paleæ or husk, and an accurate comparison of the chemical composition of the kernels of wheat and oat kernels is thus possible:

	Crude Protein.	*Crude Fat.*	*N-Free Extract.*	*Crude Fibre.*	*Ash.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Wheat ..	13·9	2·5	78·2	3·4	3·9
Oats ..	14·2	6·8	75·4	1·4	2·3

These figures emphasize the nitrogenous and oily character of the oat kernel; further, when compared with the figures of the whole grain, the kernel shows a very marked contrast in the amount of crude fibre and ash.

The chemical composition of the husk, except that it contains less fibre, is similar to that of oat straw, as will be seen from the following figures, which refer to Abundance grown at two centres in 1921.

	Husk.		*Straw.*	
	Centre 1.	*Centre* 2.	*Centre* 1.	*Centre* 2.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Protein	1·49	2·64	2·05	2·19
Ether extract ..	0·79	0·74	1·61	2·09
Fibre	33·98	32·67	42·46	42·64
Carbohydrate.. ..	57·23	58·68	47·62	47·05
Ash	6·51	5·27	6·26	6.03

When used for stock-feeding, oats may be bruised, *i.e.*, crushed, or ground into a meal, but they are rarely consumed with the husks removed. Thus, as crude fibre has a limited value for feeding, and since by far the larger proportion of the amount present in the whole grain is found in the husk, it is evident that the quantity of the latter is a good criterion of the relative value of different varieties and samples.

The quantity of husk varies with the variety, the season, the soil on which the crop is grown, and to some extent with the time of sowing, etc. Of the commonly cultivated varieties the two winter sorts, Grey and Black Winters, with from 20 to 23 per cent., show the lowest husk content. The highest husk figures are found in a few varieties such as Storm King and Black Tartary, which not uncommonly exceed 30 per cent., but the normal figure for the more generally grown varieties, such as Abundance, Victory, etc., is about 25 per cent.

The effect of environment on the quantity of husk is demonstrated in a striking manner by such varieties as Potato and Sandy, which in

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northern districts are characterized by a relatively low husk content, but when grown in drier and hotter districts, such as the south-east of England, produce grain of distinctly inferior quality. These varieties probably represent extreme cases, and under the reverse conditions, that is, when varieties commonly grown in the south are grown in the north, they do not exhibit a corresponding reduction in grain quality. On the other hand, varieties such as Black Tartary are invariably more successful in the south-western counties than in the north or east.

The date of sowing has a material effect on the final quality of the grain, for since the extent to which the grain is filled, and consequently the proportion of husk to kernel, depends largely on the ability of the plant to sustain itself in full growth and vigour, any conditions which ensure this must be valuable. Early sown corn usually develops a more elaborate root system than corn sown later, and is in consequence better enabled to obtain a full supply of moisture during the period of rapid vegetative development. In seasons characterized by conditions of excessive rainfall and lack of sunshine, or, on the other hand, of severe drought, the percentage of husk tends to be higher than when the climatic conditions approximate more nearly to the normal. In seasons of ample rainfall the benefit of early sowing is not so apparent, but under conditions of limited supplies of moisture its value is very evident.

In addition to differences in the quantity of husk, and consequently to substantial increases or otherwise in the fibre, the kernel itself exhibits considerable variation in chemical composition. The Sixty-Day oat, so named after its supposed length of period of growth, has been shown to give 20 per cent. of protein, and the wild oat, *A. fatua*, nearly 13 per cent. of oil (Professor R. A. Berry, "Composition and Properties of Oat, Grain, and Straw," *J. Agric. Sci.*, vol. x., part iv., 1920).

These are extreme cases, but nevertheless probably represent real genetic differences. Amongst more usually cultivated forms there is evidence of variation in the protein and oil, but with so little conformity of direction that it is difficult to formulate an idea of general tendencies. One condition, however, is fairly consistent, and that is that the protein and oil do not increase or decrease concurrently, consequently a loss in feeding value attributable to the diminution of one constituent tends to be compensated for by an increase of the other.

In the manufacture of oatmeal the value of a low percentage of husk and of a correspondingly high percentage of kernel is clearly evident. Similarly a low percentage of husk for feeding, whether to ruminants, pigs, or poultry, is the criterion of quality in oats, whether they are crushed or ground into meal.

There is no evidence to show that the colour of the husk has any effect whatever on the actual feeding value of the grain. Nevertheless, preferences and prejudices do exist, and the balance of opinion appears to favour an oat with a white grain. In the case of oats used in the manu-

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facture of oatmeal such a preference is readily justified, for while the presence of small portions of the paleæ of white-grained oats in the meal is not serious because it is less obvious, a corresponding quantity of the husk of a coloured grain may be decidedly objectionable from a commercial point of view.

With the increase in the poultry population which has taken place more particularly since the War, there has been a corresponding increase in the quantity of oats used for poultry food, now estimated at 500,000 tons per annum. Much of this is utilized as whole grain, but large quantities are consumed as meals—a well-known form being "Sussex ground oats." This meal (which has not necessarily any connexion with the county of that name) is produced by grinding whole oats only, in such a manner that both the husk and kernel are reduced to a state of fineness sufficient to permit them to pass through a sieve of a certain diameter of mesh. Treatment in this manner permits of the use of any description of oat, and because of their "condition" foreign oats are preferred frequently. But no amount or degree of grinding will remove the indigestible fibre, although fineness of division may facilitate its passage through the alimentary canal of an animal.

Digestibility trials have demonstrated the influence of the fibre content of oats when fed to poultry. Varieties with relatively lower fibre content exhibit a higher total digestibility, and consequently in any effort at improvement of the oat crop this attribute of the grain must receive full recognition (E. T. Halnan, "Digestibility Trials with Poultry. IV.—The Digestibility of Certain Varieties of Oats," *J. Agric. Sci.*, vol. xviii., part iv., October, 1928; *idem.*, "The Rôle of Fibre in Poultry Feeding," *Paper No.* 34, *4th World's Poultry Congress*, 1930, *Proceedings Section B*).

Improvement of the Crop—Although on an acreage basis oats are the most important cereal crop in the British Isles, they have not received the attention of plant breeders commensurate with that devoted to wheat and barley. The utilization of the greater portion of the crop on the farm, and consequently the lack of stimulus that arises from commercial demands, may furnish a reason for this condition.

Further, the farmer himself is not fully conversant yet with the differential value of varieties based on their feeding value. With the growing necessity of utilizing home-grown foods to a larger extent, there is a tendency towards a more critical examination of feeding values, which must ultimately focus more attention on variation in the feeding quality of the oat grain.

The monetary difference between the cost of production and the amount realized for a crop is the final test of the value of all efforts at plant improvement, and no one crop attribute, whether it be high grain yield, high quality, good straw, or high disease resistance, is of paramount importance. All these various attributes must receive attention concurrently, and this method of attack has already produced many good varieties, all of them being relatively prolific, and most of them possessing sufficiently good straw. By crossing the best of the well-established varieties, new forms possessing higher yielding

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capacities are being produced at most plant breeding stations from time to time.

A further hopeful line of improvement is found in an attempt to circumvent some of the obvious limiting factors of productivity. In an earlier passage reference was made to the detrimental effect of excessive rainfall and of heat and drought on the quality of the grain. When the crop as a whole is viewed in relation to these extremes of climatic conditions, the effects of a lengthened period of growth in wet seasons, and the devastating effect of insect attacks, accentuated by the inability of the plant to maintain continuous growth in very dry periods, are very evident.

A full yield of grain depends, amongst other circumstances, on the ability of the plant to transfer the material elaborated in the stem and leaves into the grain. But the difficulty in an abnormally wet season, which is usually also deficient in bright sunshine, is that the period of transference is so prolonged that it extends into a time of the year when complete filling becomes impossible, and the crop, if it is to be saved at all, must be cut before it is even passably ripe. Similar conditions to these frequently occur in northern districts with late-ripening varieties, which, although they are known to be potentially prolific, fail to produce good results because they can never reach a state of complete filling. In Sweden the Dala and other early ripening oats selected from the ordinary oats grown in that country have been selected for propagation, and exhibit a decided improvement in the direction of earliness to the bulk of oats from which they were taken. At Cambridge a French variety, Noir très Hâtive, and an Argentine oat, both exhibiting earliness in ripening, have been crossed, and amongst the resulting progeny some forms have been found possessing a greater degree of earliness than that of either parent. Unfortunately, early ripening forms are very frequently deficient in quality of grain, and those just mentioned are no exception in this respect. Whether the association of early ripening and high husk content can be broken down is an issue for further investigation.

Proceeding to the effect of heat and drought: in these we are dealing with climatic conditions, which are serious limiting factors in the eastern and south-eastern districts of England. This is especially the case when, as so often happens, a drought occurs in the late spring or early summer—at a time when the oat plants should be attaining their maximum vegetative development. A deficiency of moisture at this stage greatly delays growth, and, more serious still, it leaves the plant a ready prey to the insect pest, Frit Fly (*Oscinella frit*), an attack of which, when combined with an extended period of drought, may result in the complete ruin of the crop (Fryer and Cunliffe, *Ann. App. Biol.*, vol. xi., 54-72, 465-481; 1924; *ibid.*, vol. xii., 508-515, 516-526, 1925).

In Sweden it has been found that some varieties are less seriously attacked by the Frit than others, and if such a claim can be substantiated in England, there is a possibility of obtaining a long, new series of Frit Fly-resistant varieties by hybridization (N. Cunliffe,

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"Studies on *Oscinella frit* Linn.," *Ann. App. Biol.*, vol. xvi., No. 1, February, 1929).

There is considerable evidence that the varieties best able to withstand Frit Fly attack are those possessing a good tillering capacity. Amongst spring oats the capacity to recover from attack is possessed in a larger measure by varieties which not only tiller abundantly, but which produce their tillers at about the same time. Concurrently with the production of early ripening types for late-ripening districts, attempts are consequently being made to secure varieties possessing such a tillering capacity as enables them to recover, at least in some measure, from a Frit attack.

Another means of circumventing the Frit Fly pest is the adoption of the practice of sowing in the autumn, and this necessarily involves the use of winter hardy varieties. In two ways autumn sowing is helpful: first, if the soil conditions and the weather immediately following drilling are favourable, autumn-sown cereals usually develop a more elaborate root system than those sown in the spring, and are consequently less liable to suffer from the effects of drought; thus, even where the Frit-Fly attack is not serious, the ability to sustain uninterrupted development is a valuable asset. Secondly, true winter oats, such as Grey and Black Winter, are characterized by a high tillering capacity, and if attacked by Frit Fly in the spring can afford to lose some tillers without seriously affecting the ultimate yield of the crop.

Further, since the Frit Fly makes its first appearance in the south in April, and its maximum appearance towards the end of May, the main shoots and tillers of autumn-sown varieties are at that time so well developed that it is the younger tillers only which suffer, and they, in normal conditions, would not make a large contribution to the ultimate yield of the crop. For these reasons, and because such a practice facilitates work on the farm in spring, the cultivation of winter oats is a matter of growing importance in areas of low rainfall. In areas where there is normally an abundant rainfall in the early months of the year, spring-sown oats are able to grow sufficiently rapidly and unchecked, and consequently in most seasons suffer very little from the pest. (See Insect Pests, Measures of Controlling.)

Although possessing many features of agricultural value, the true winter forms of oats at present in general use are characterized by long, fine, resilient, but weak straw, a feature rendering them liable to "lodge" under any soil conditions, but making them totally unsuited to the more fertile soils, and accordingly limiting their cultivation over wider areas.

The attempt to produce improved winter forms is being made at several plant breeding stations at the present time. It is clearly a many-sided problem, for while the main object is to obtain winter hardiness associated with better standing straw, it is desirable at the same time to secure a quality of grain which, if not equal, is not too greatly inferior to Grey or Black Winter. The best standing straws are found most commonly amongst the true spring oats, and in associa-

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tion with grain which, although not inferior to the general average of spring varieties, is definitely inferior to Grey and Black Winter.

Although winter hardiness is unquestionably due to definite genetic factors, a measure of its expression in any variety is always relative to the degree of temperature to which a crop is exposed. In some seasons, spring varieties, when autumn-sown, may survive the winter, but in one such as that of 1928-29 they suffered almost complete extinction. On the other hand, the progenies of crosses made between spring and winter forms exhibit gradations of ability to resist winter conditions, and investigations now in progress at Cambridge indicate that better standing straw than the winter hardy parent, associated with a satisfactory degree of winter hardiness (although not necessarily that of the winter-hardy parents), can be obtained. These valuable attributes are in many cases associated with a grain quality equal or only slightly inferior to that of the winter parent. (See Winter Hardiness and Drought Resistance.)

With the increased cost of all agricultural operations, and with a demand for more intensive farming rendered possible by the liberal use of artificial manures, the necessity of the provision of better standing straw of all cereals is imperative. It is clearly useless to increase the grain-yielding potentialities of cereals if the financial value of the enhanced produce is absorbed in the additional cost of securing the crop as a result of its being too badly lodged to permit of harvesting with the self-binder in the usual way. (See "Wheat-Breeding Investigations," *Min. Agric. Research Monograph*, No. 4, 1926; also Barley and Wheat.)

A hundred years ago the varieties of oats in cultivation functioned in the dual capacity of grain and fodder producers. It is noteworthy that changes in the character of varieties produced within the last thirty to forty years have involved a gradual substitution of varieties that are essentially grain producers for the earlier dual purpose forms. While the ratio of straw to grain in the former is low, it is relatively high in the latter, and although the standing power of the straw of the more recent introductions is usually decidedly better, its fodder value is correspondingly inferior.

It is interesting to note also that the demand for the older varieties still persists in districts characterized by conditions of inferior soil fertility, such as parts of Scotland, Wales, Northern Ireland, and north-west England. It is probable that in these varieties we have a further illustration of the adaptation to less fertile soil conditions noted in old varieties of other cereals, such as Archer barley and Rivet wheat.

The question of the degree of association between stiff-standing straw and a high percentage of husk in the grain is an aspect in the improvement of the crop that is receiving attention. With the gradual but inevitable increase in soil fertility the direction of change will necessarily be towards forms with improved straw, but fortunately there are indications already that this does not inevitably imply the rigid straw usually found concomitantly with high husk content. Resilient

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straws that move with the wind rather than offer a rigid resistance to it have been isolated, and are found to possess the additional value of association with grain of good quality.

General References.—A. Zades, "Der Hafer," Gustav Fischer, Jena, 1918; A. I. Malzew, "Wild and Cultivated Oat," *Bull. Appd. Bot., Genetics and Plant Breeding Suppt.* 38, Leningrad, 1930. H. H.

OATS, FATUOID—Fatuoids or false wild oats, so called from their resemblance to *Avena fatua*, the wild oat, have been found in nearly all varieties of cultivated oats, both of *A. sativa* and *A. byzantina*. Since 1884 there has been considerable discussion as to whether they arise from natural crossing with *A. fatua* (see Zade, Tschermak, and Crepin), or directly from *A. sativa* by some form of mutation. The origin-by-natural-crossing hypothesis was, in the writer's opinion, effectively ruled out by the work of Nilsson-Ehle, 1911, *et seq.*, and Akerman, 1921, who showed that apart from the group of characters comprising the fatuoid complex, fatuoids are similar to normal oats of the variety in which they arise. The fatuoid complex consists of a strong, twisted, geniculate awn on the lemma of all the grains, a large "sucker mouth" or abscission layer at the base of each grain, and a tuft of hairs surrounding this base; this is inherited as a unit. The recent discovery by Jones of association between spikelet number, the absence of colour, and the fatuoid complex in one strain demands a wider view of the nature of the mutation, but only emphasizes Nilsson-Ehle's general conclusion that fatuoids are mutants and not the products of natural crossing. Further evidence is provided in the discovery by Hunter, and also by the writer, of chimerical plants bearing some fatuoid and some normal *sativa* spikelets or panicles. Since the fatuoid characters of the grains are composed of the maternal plant tissue, fatuoids of chimerical origin must have arisen by some form of somatic mutation. Natural crossing cannot directly have played any part in their production.

On the other hand, it seems certain that *A. sativa* is a species of hybrid origin, though of considerable antiquity, and that this ultimate hybridity is related to the origin of fatuoids. The species of *Avena* fall naturally into three systematic groups, which are characterized by their chromosome number. (See Cytology.) *A. wiestii*, *A. brevis*, *A. strigosa*, and *A. nuda biaristata*, for example, have 7 chromosomes in their somatic cells and 14 in their germ cells; *A. barbata* and *A. abyssinica* have 14/28 chromosomes; and *A. sativa*, *A. nuda*, *A. byzantina*, *A. sterilis*, and *A. fatua* are hexaploids having 21/42. The 42 chromosomes of these hexaploids typically form twenty-one pairs at the time of germ cell formation, but some irregularities of pairing occur. Correlated with the triplicated or hexaploid chromosome set is the fairly common occurrence of triplicate genetic factors. The genetic and cytological behaviour is, in brief, such as would be expected if they had arisen by chromosome duplication following interspecific hybridization, as the species *Primula kewensis* and the genus *Ægilotricum*, for example, have done under experimental conditions.

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If this assumption of a hybrid polyploid origin is correct, it would not be surprising to find that rearrangement, reduplication, or loss of whole or part chromosomes in the hexaploid species would produce, or allow to appear, characters already known in other species. This is the general conception favoured by the writer to explain the correlation he has observed between abnormal chromosome conditions and the occurrence of fatuoids.

The fully developed or homozygous fatuoid form does not usually appear directly from *A. sativa,* but as a segregate from an intermediate form, the heterozygous fatuoid. The mutation producing heterozygous fatuoids, whatever its nature, may apparently occur in either somatic or germ cells. Heterozygous fatuoids similar in appearance may be very different in genetic constitution. There are three principal genetic types closely analogous to the types of speltoid wheat investigated by Nilsson-Ehle and others. In conformity with speltoids they are called A, B, and C series. The commonest type, the A series, on self-fertilization, produces homozygous fatuoids, heterozygous fatuoids, and normal oats in ratios approximately 1 : 2 : 1. All three classes of segregates usually appear to be of equal vigour. B series heterozygous fatuoids typically produce heterozygotes like themselves and normal oats in a ratio of about 5 : 1, and only a very few homozygous fatuoids. The latter are dwarf and sterile. Other strains which are included with B series may, however, give as many as twenty heterozygotes to one normal. C series heterozygous fatuoids produce heterozygotes and normal oats in about equal proportions, and only a few homozygous fatuoids. These latter are of low vigour, but not as dwarf or sterile as in the B series.

These three series are characterized by different chromosome numbers and behaviour, and their genetic ratios are in accordance with expectation calculated from cytological observations. Thus, the A series strains have 42 chromosomes in all three classes of segregates, but whereas in the normal segregates these almost always form 21 pairs at the reduction division, the 42 of heterozygous fatuoids are often arranged as 19 pairs, one group of 3 and 1 unpaired chromosome, and in homozygous fatuoids they are often arranged as 19 pairs and one group of 4. In all the B series strains the heterozygous fatuoids have only 41 chromosomes which regularly form 20 pairs and leave 1 chromosome unmated. This odd chromosome is very frequently lost in the course of the reduction division. Hence, the germ cells mostly possess only 20 chromosomes. There is evidence that ovules function readily with either 20 or 21 chromosomes. On the other hand, pollen grains with only 20 are severely handicapped, so that though relatively few with the normal complement of 21 are formed, it is chiefly these that effect fertilization. The different genetic types included in series B are distinguished cytologically by the frequency with which the odd chromosome is lost, but there is no evidence so far on the cause of the differential frequency.

The dwarf homozygous fatuoids segregated from B series have only 40 chromosomes, and their reduction divisions are extremely irregular.

OATS, FATUOID (*Continued*)—

Series C heterozygous fatuoids have 43 chromosomes. The extra chromosome nearly always forms a trivalent with one of the pairs. There is therefore very little chromosome loss, and germ cells with 21 and 22 chromosomes are formed in more or less equal proportions. Series C gives the ratio it does because ovules with either chromosome number function readily, while pollen grains with 22 chromosomes are seriously handicapped. The dwarf homozygous fatuoid segregates of series C have 44 chromosomes.

The hypothesis devised to account for these observations is a development of Winge's scheme for speltoids, as follows:

The hexaploid chromosome set of *A. sativa* is symbolized as—

$$\begin{matrix} 1_A & 1_B & 1_C & 2_A & 2_B & 2_C & \ldots\ldots\ldots\ldots\ldots & 7_A & 7_B & 7_C \\ 1_A & 1_B & 1_C & 2_A & 2_B & 2_C & & 7_A & 7_B & 7_C \end{matrix}$$

The B chromosome pair of one of these sets is assumed to carry genetic factors for fatuoid grain characters, but their effect is supposed to be masked by factors for the *sativa* grain characters which are carried on the C chromosomes of this set. The fatuoid characters, on this hypothesis, appear whenever through chromosome aberrations the balance of B and C is upset and there is an excess of B chromosomes. Thus, series A heterozygotes arise through an interchange, brought about by faulty chromosome pairing, and they are represented by $\frac{A\,B\,B}{A\,B\,C}$. Series B heterozygotes arise through loss of a C chromosome, and are $\frac{A\,B\,o}{A\,B\,C}$. Series C heterozygotes arise through chromosome aberration giving cells with an extra B chromosome, and are $\frac{A\,B\,C\,B}{A\,B\,C}$. The homozygous fatuoids of A, B, and C series are respectively $\frac{A\,B\,B}{A\,B\,B}$, $\frac{A\,B\,o}{A\,B\,o}$, and $\frac{A\,B\,C\,B}{A\,B\,C\,B}$.

Since his last publication on fatuoids (1927) the writer has found many complications, but none which affect the general validity of this scheme. Some of the complications are due to aberrations affecting only parts of chromosomes, and others may be explained by crossing over between chromosomes which do not normally pair.

Besides the ordinary fatuoids, mutant forms from *A. sativa* or *A. byzantina* have been found by Jones, Coffman, Parker and Quisenberry, Stanton, Coffman and Wiebe, and the writer, which are rather nearer in appearance to *A. sterilis* than to *A. fatua*, and are now called steriloids. Jones has studied also types with grains bearing fatua-like awns, but sativa bases. Cytological studies still in progress show chromosome abnormalities in all the types found by the writer.

Jones in a recent paper gives detailed genetic analyses of different fatuoid, subfatuoid, and other mutant types. He emphasizes the great frequency of A series fatuoids and other 42 chromosome mutant types, and the comparative rarity of the B and C series fatuoids. His

OATS, FATUOID (*Continued*)—
opinion is that chromosome aberrations alone are not sufficient to explain all the facts, and he suggests a modification of the writer's hypothesis. It is, briefly, that, besides chromosome aberrations, gene mutations occur in the C chromosome, and affect the degree of expression of fatuoid and other factors located on the B chromosome. This distinction is very important in relation to the wider aspects of the problem of the nature of mutations, and it is to be hoped that further genetic and cytological analyses of oat mutants will give a conclusive decision on the relative merits of these hypotheses.

Whichever is correct, it is quite clear that fatuoids arise directly from *A. sativa* and not through natural crossing with *A. fatua*, though such crossing does occur and is responsible for the appearance of forms which may be confused with real fatuoids.

Though fatuoids are an undesirable impurity in seed oats, they have never been found to be a serious weed menace or to become very numerous in any variety. The lowered viability of the heterozygotes and the absence of fertile homozygous fatuoids in the B and C series would of course ensure their elimination. The chief difference between A series fatuoids and *A. fatua* from the weed standpoint is that, as Howes, Criddle, and Garber and Quisenberry have shown, fatuoids do not possess the property of delayed germination. It is this character, combined with the habit of shedding its grains when ripe, which seems to make *A. fatua* a serious weed menace, whereas the shedding habit, without delayed germination, found in fatuoids, probably serves to reduce their frequency under most conditions of cultivation.

A fairly complete bibliography of the subject is given in the papers of Huskins (*J. Genetics*, xviii., 315-364, 1927) and Jones (*ibid.*, xxiii., 1-68, 1930).

C. L. H.

OILS—These liquids are usually divided into three classes—viz., essential oils, mineral oils, and fixed oils. The first are only of remote interest to the British farmer, though in other countries gardens and even larger tracts are to be found devoted to their cultivation. They are derivatives of terpenes, hemiterpenes, and hydrocarbons of the camphene and menthene series, found in various parts of plants, as, for instance, the flowers in rose, violet, jasmine, and orange (neroli); the sepals, bracteoles, etc., in lavender; the foliage in rose geranium, thyme, and wintergreen; the wood of sandalwood and cedars; the rind of the fruit in orange and other citrus fruits; and the roots of *Iris florentina* (orris root). For further details see L. H. Bailey, " Standard Cyclopædia of Horticulture," p. 2547 *et seq.*, 1927; also from the chemical point of view, F. Heusler, " The Chemistry of the Terpenes."

The second class of oils touch farming rather by their use than in their production; they are hydrocarbons obtained from natural petroleum deposits, and by distillation of coal, wood, lignite, peat, etc., and are used as oil fuels of various kinds, burning oils, lubricants, etc. (See Paraffin.)

The third class is of considerable importance in British agriculture, which produces in some cases the raw material out of which they are

OILS (*Continued*)—

extracted, as in linseed, and in a great many other cases uses the bye-products from their production, as oil cake. Chemically they are fats, *i.e.*, the glycerol esters of fatty acids, and occur in animals, plants, and fishes. Being fats, they may be saponified. Opinion is divided among botanists as to their occurrence in the plant; there is certainly an emulsion, but whether the oil or the cytoplasm constitutes the disperse phase is in dispute. In most cases, when they are extracted from plants, it is the seed that yields the oil. In extraction the crushed seeds are heated, and the oil pressed out of them at a high temperature; in a more recent process, the first portions of the oil are got out from the hot mash by centrifuging at the high temperature; this has the advantage of reducing the plant necessary for dealing with a definite quantity of seeds in a given time. The matter remaining in the presses is made up into oil cakes of various kinds (*q.v.*).

Some of the fixed oils, *e.g.*, linseed oil, also hemp and poppy oils, have the property of drying up when spread out—for instance, by painting on woodwork. They do this by absorption of oxygen from the air, which reaction appears to be autocatalytic. Other oils, such as almond and olive oil, do not show this property to anything like the same degree.

The drying properties of oils are in almost direct proportion to their so-called *iodine values*. The iodine value may be simply defined as the amount of iodine absorbed by 100 grms. of the oil from iodine chloride, and is a measure of the degree of unsaturation of the carbon linkages with which the drying property is closely associated.

Fixed oils, like fats, have generally a tendency to go rancid.

Cotton-seed, linseed, ground-nut, and other oils can be changed into artificial fats by hydrogenation at a high temperature in the presence of nickel catalysts, and these substances are used in the manufacture of various grades of chocolates, margarine, soaps, etc. Hardened castor oil finds a use as an electric insulating medium.

ONIONS—See Market Gardening ; Vegetable Breeding.

ORDNANCE SURVEY—The Ordnance Survey of Great Britain, which for accuracy, clarity, and the number of scales on which it is produced has become the envy of the civilized world, was begun as early as 1784, when Major-General Roy measured a base-line of 27,404 ft. on Hounslow Heath, from which the primary triangulation, carried out by the Royal Engineers, was thrown out. This was only completed in 1858. From 1840 to 1863 there was much discussion as to the most suitable scales for the large-scale topographical maps. At first it had been the modest intention to produce a map sufficiently accurate on a scale of 1 in. to a mile, but in 1863 it was finally decided to make 6 ins. to a mile the standard large-scale topographical map, with a cadastral map on a scale of 25·344 ins. to a mile for all areas in any way in cultivation. These maps are now published, the former for every square yard of the country in about 15,000 sheets, the latter for all but mountain and waste areas. At first the Geological Survey was carried out by the Ordnance Survey Department, but since 1853 this has been under

ORDNANCE SURVEY (*Continued*)—

separate direction. As such maps are of importance in farming, they will be dealt with in this article. The Ordnance Survey itself is no longer under the control of the War Office, but under the Ministry of Agriculture and Fisheries.

Projections and Datum Level—The surface of the country is really a part of the surface of a spheroid, and it is clearly impossible to represent this on a flat surface without some distortion somewhere. This is easily seen in the ordinary Mercator's map of the world, in which Greenland appears far larger than India, although, in fact, it is very much smaller. For smaller areas the distortion is, of course, less, but is still present on the largest scale plans, where, however, it is so small as to be quite negligible. All ordnance maps of Great Britain are on some form of "conical projection"—that is to say, a conical surface is supposed to touch the surface of the earth at the part where the map is to be made, and the features of the surface are projected on to this conical surface, which can then be rolled out—"developed" as it is called—on a flat surface, giving a map. The form of conical projection used varies with the scale of the map, and will be discussed when these scale plans are dealt with.

For measurement and representation of height of land above sea-level some fixed mean sea-level must be adopted, since tides, drift currents, storms, etc., are continually altering the actual level of the sea. Originally the mean level of the sea at Liverpool was taken as the standard; this was determined by only a fortnight's observation, and has recently been discarded because the position of Liverpool on a tidal river is unsuitable, also a general cumulative error partly due to imperfections in the instruments and partly to the methods of revision has been discovered (see "The Second Geodetic Levelling of England and Wales, 1912-21"), and this has been complicated by local errors dating back to 1840. Hence, a new datum has been chosen, founded on hourly sea-level observation lasting over six years, 1915-21, at Newlyn in Cornwall. All sheets published since April, 1929, show the variation due to locality, and contours and levels are corrected to the Newlyn datum.

Scales and Maps—Apart from a general geological map of the whole country on the scale of 25 *miles to* 1 *in.*, the smallest scale published is that of 1 : 1,000,000 or 15·782 *miles to* 1 *in.*, showing the whole country in two sheets, hill shading brown and coastal water blue on the conical projection with rectified meridians and two standard parallels. In this the cone of projection has its apex on the axis of the earth produced, and cuts the surface of the spheroid in the region of the map; thus two parallels are correct and all meridional lengths may be made so. On this same scale there is also published a physical map of England and Wales orographically coloured, with contours at 200, 400, 800, 1,200, and 2,000 ft.; *i.e.*, lines are drawn connecting points on the surface having those altitudes, and the intervening parts of the land surface are suitably tinted to show the elevation; *e.g.*, land between sea-level and 200 ft. is green, that between 200 and 400 ft.

ORDNANCE SURVEY (*Continued*)—

faint brown, and so on to higher levels. There is also a map of Roman Britain showing marshes, roads, settlements, potteries, etc., with an explanatory leaflet, the whole contoured and orographically coloured as in the physical map. The British sheets of the "Carte Internationale du Mondeau Millionième" are also issued by the Ordnance Survey Office, except the sheet NM 31 including (in England) Kent, part of Sussex, and Essex, which is published by France. This map is on a modified polyconic projection.

The next larger scale is that of 10 *miles to* 1 *in.* covering Great Britain; in the older editions, the southern part, representing England and Wales, is on Airy's projection, the Scottish on Bonne's. Airy's projection may be described as a best mean projection determined by the method of least squares between the zenithal equi-areal, in which form is distorted and areas are correct, and the stereographic, in which the form is correct but the areas distorted. In Bonne's projection, which is a variety of the conical, a standard meridian is chosen, and the degrees of latitude set out on it at their true rectified distances, the parallels being circular arcs along each of which points are marked off at the true distances along the parallels of the spheroid at which the meridians cut them. These points are then joined for the meridians. It shows areas correctly, but form is distorted. In the newer editions both England and Wales and Scotland are on Cassini's projection (see below). The map is published both in outline and orographically coloured. There are no geological maps on this or the previous scale.

On the scale of 4 *miles to* 1 *in.* there are maps of the whole country, both topographical and geological; the projection for England and Wales for these and all larger plans is that known as projection by rectangular spheroidal co-ordinates (Cassini's projection). In Scotland the sheets of the ¼-in. and 1-in. map were originally published on Bonne's projection (see above) and to a different meridian. The process of bringing these to the same meridian which passes a point in Delamere forest in Cheshire, and to the same projection as England and Wales, is now complete. In projection by rectangular spheroidal co-ordinates the meridian is chosen, and a cylinder (*i.e.*, a cone with apex at an infinite distance) is imagined to touch it all round; the axis of the cylinder, therefore, passes through two points on the equator, 90° E. and W. respectively of the meridian. Lines at right angles to the meridian consequently represent great circles at right angles to the meridian, differing therefore from a parallel, but the error is only about 1 per mille in the scale for 150 miles each side of the central meridian. The ¼-in. map is published in outline without contours, or orographically coloured with contours at each 200 ft. In Scotland there is also a hill-shaded edition which is not to be reprinted when stocks are exhausted. The revised geological map on this scale is available for the whole of the country in *solid*—that is, giving the geological structure of the earth's crust generally at the place. There are also some sheets in *drift* which show the surface deposits which frequently overlie the deeper permanent geological features. These

ORDNANCE SURVEY (*Continued*)—
drift maps will naturally often have a greater interest for the farmer than the solid. The topographical, orographically coloured maps are also issued on the ¼-in. scale in the form of atlases of England and Wales, Scotland, or the two together for Great Britain.

On the scale of 2 *miles to* 1 *in.* the survey maps are published in two forms, coloured with hill shading and orographically coloured. Contours are shown in both these maps at 100 ft. intervals. The projections are as in the older ¼-in. maps, *i.e.*, Cassini's for England and Wales, Bonne's for Scotland. There are, in addition, special district maps and county administrative maps showing boundaries of unions, rural and urban districts, municipal and county boroughs and civil parishes, also parliamentary divisions published on the ½ in. scale. The Ministry of Transport road map on this scale is issued by the Ordnance Survey Office, and shows the official road classification in colour; contours and hill shading are omitted in these maps. There are no geological maps on this scale.

The scale of 1 *in. to a mile* provides perhaps the most famous of ordnance survey maps of Great Britain. It is issued in four forms: (*a*) The popular edition based on the third revision, distinguishing four classes of roads, water blue and woods green, contours red or orange, at 50 ft. intervals throughout, parks, orchards, rail and road crossings and bridges, and many other features; (*b*) an outline edition of the above, water blue, contours red, the rest black for engineering purposes; (*c*) the second revision coloured (1901-12), with hill shading and contours at 100 ft. intervals. This map shows civil parish boundaries, which are omitted in the popular edition, and is generally better produced, but is being superseded by the latter, and many sheets are already out of print. (*d*) The engraved black outline series (second revision), printed direct from the copper plate, is quite the best of the four, where certainty as to minute details is desired; the woods are shown in character as coniferous, mixed, and deciduous; while this is so in the other forms, it is liable to be obliterated in the process of reproduction. The Scottish maps in the popular edition (third revision) have been brought to the English projection and meridian, and are now published for all but Orkney and Shetland, Caithness and the Hebrides. The engraved and old coloured series remain on Bonne's projection. On this scale there are many coloured and outline district maps, as well as tourist maps of special districts in hypsometric layer tints. The county administrative map of London is on this scale. Specimens and further particulars of the topographical small-scale maps are given in a brochure issued by the Ordnance Survey Office at 1s.

One inch to a mile is the scale chosen for the principal geological map of Great Britain. Of this there are maps of the whole country, except Orkney, Shetland, the Hebrides, and a few sheets in Inverness and Sutherland. The old series of England and Wales was hand coloured on a hill-shaded 1-in. topographical map, and was expensive, but a veritable work of art. The new series may be had either hand coloured or colour printed. Scotland may be had either hand coloured

ORDNANCE SURVEY (*Continued*)—

or colour printed. These are all in solid, but about half of the sheets are already available in drift, and, doubtless, the whole will eventually become so.

A Ministry of Transport road map of London and environs is issued on a scale of 2 *ins. to a mile.*

The map on the scale of 6 *ins. to a mile,* and those on larger scales, are too large to enable them to be referred to a single meridian by rectangular spheroidal co-ordinates, as on these large scales the distortion would then be quite considerable in outlying sheets. Hence the counties are grouped, and a suitable meridian chosen for each group; *e.g.*, the 6-in. and larger scale maps of Cambridgeshire, Huntingdon, Norfolk and Suffolk are projected on the *meridian* of Danbury church spire, although this is actually in mid-Essex; Bedfordshire, Hertfordshire, Essex, Middlesex, and London are on the meridian of St. Paul's Cathedral dome. Hence we must not expect the marginal sheets of Essex and Suffolk to *exactly* agree, although the difference is, of course, very slight. Those of Essex and Hertfordshire, on the other hand, will do so. For the whole country some thirty-seven meridians are employed.

Space does not permit details of features shown on this and larger scales; they are extremely full, and on the 6-in. map the widths of all roads are correctly shown to scale, except in the centre of large towns, where the widths are somewhat exaggerated to give room for the street name. Fields, footpaths, etc., are clearly shown, and surveyed contours every 100 ft., with, frequently, interpolated ones at 25-ft. intervals. Heights of bench marks are given to 0·1 ft. All civil boundaries and areas of parishes appear (see Fig. 1, Plate XVIII). For most engineering purposes this is a suitable scale, notably all plans for new railways have to be submitted to the Houses of Parliament on this scale when the requisite powers are applied for. It is the largest scale on which contours are shown, and the largest which covers the whole country; there is no piece of waste mountain top or outlying island of which a 6-in. map cannot be obtained. Town maps in colour are also issued on the scale of 6 ins. to a mile.

Geological maps on the 6-in. scale do not cover anything like the whole of the country, being confined for the most part to those areas where mining is in progress, but the ordinary 6-in. sheets can usually be obtained overprinted in blue with the geological features, and MS. copies can be had of any, as well as certain vertical and horizontal sections. Explanatory brochures are issued with most of these sheets, and also with the ordinary sheets of the 1-in. Geological Survey previously mentioned.

As a general map of individual farms, the one recommended for the majority of cases is that on the scale of $\frac{1}{2500}$ or 25·344 *ins. to a mile.* On these maps almost every conceivable feature of the landscape is shown accurately to scale (see Fig. 2, Plate XVIII). Even in large towns the streets are shown their true width. Woods are distinguished as coniferous, mixed, and deciduous; orchards, brushwood, and isolated trees and bushes, except hedgerow trees, are

PLATE XVIII

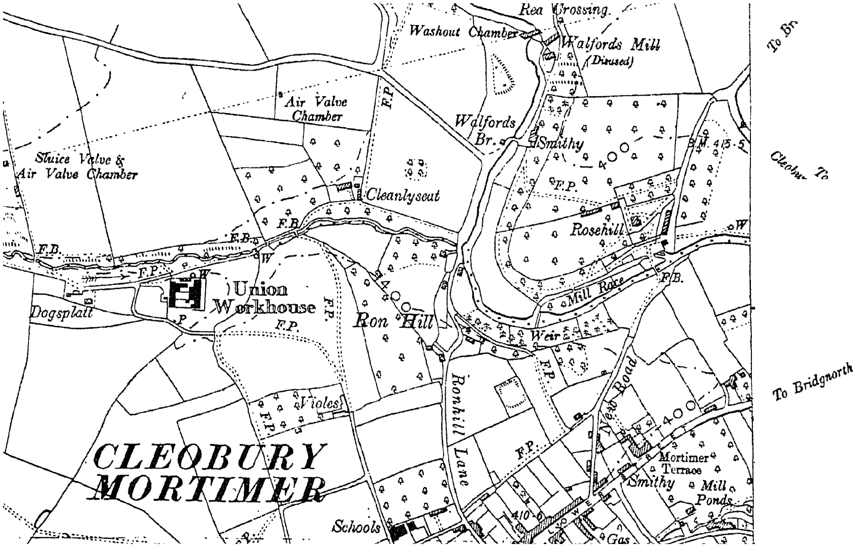

FIG. I.—REPRODUCTION OF ORDNANCE SURVEY MAP ON SCALE 6″ TO ONE MILE.

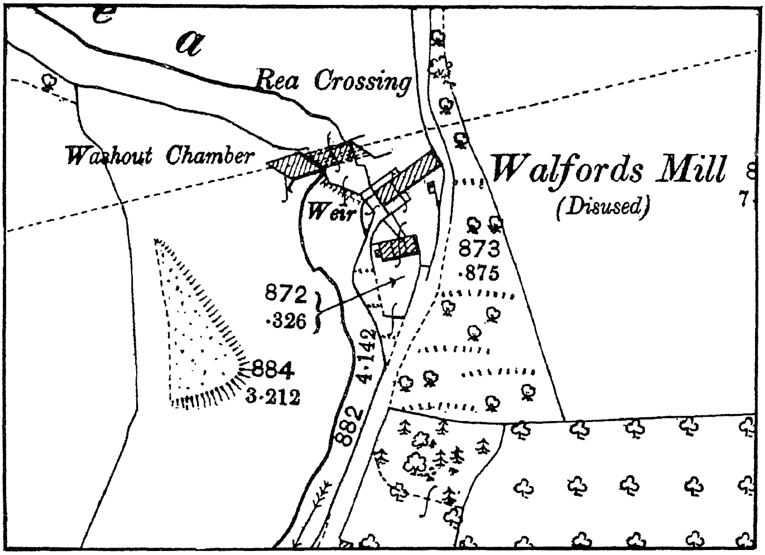

FIG. 2.—PORTION OF THE ABOVE FROM THE 1/2500 MAP.

By permission of the Director-General of the Ordnance Survey.

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ORDNANCE SURVEY (*Continued*)—

distinguished. Rough pasture, marshland, reeds, osiers, furze, quarries, sand pits, refuse heaps, shingle, clay pits, gravel pits, springs, wells, troughs, mooring rings, etc., are all shown in character. Further, the exact areas of all fields, brooks, canals, and so forth, are given, and each parcel of land is numbered and all civil boundaries shown. Hence this map is most useful in conveyancing, for which purpose careful note is made as to whether the boundary of a parcel follows the centre of a hedge, wall, or fence, or is situated to one or other side of it or at a short distance from it on either side. As before stated, no contours are shown, but the number of bench marks, surface levels, etc., is so large that these can, if desired, be approximately sketched in. The sheets are larger, on better paper, and rather more expensive than those of the smaller scales; the usual price is 6s. 8d. per sheet.

A larger scale of $\frac{1}{1250}$ or 50·688 *ins. to a mile* is published for most populous districts. These maps are merely enlargements of those on the 25-in. scale, and so show no more detail. They are, however, convenient for some purposes, and should one be required of any district which is not published on this scale, the Ordnance Survey Office is prepared to produce one and supply twenty copies to order for the sum of £7.

Town maps on the scales of 60, 120, and 126·72 *ins. to the mile* were formerly published, but have been discontinued, except where the municipalities concerned have been willing to meet the cost of revision. The plates are still in existence, but are out of date. The 120-in. map of London is still in use.

No geological maps on a scale greater than 6 ins. to the mile are published.

Apart from the Carte Générale Aëronautique Internationale and a ¼-in. map, no air maps of this country are so far published.

The Ordnance Survey Department recently conducted an investigation into aerial surveys, and concluded that while they offered certain advantages in towns and flat country, tidal flats, forest country, etc., were quicker and involved less invasion of premises than the older methods, their general adoption is for the present not to be recommended.

The small-scale maps—that is, those on the 1 in. and smaller scales—are revised at least every fifteen years. The fourth revision of the 1-in. map has already been started, and the first sheet (Plymouth) was published in the autumn of 1930. In this revision the projection has been changed to that known as Gauss's conformal, in which azimuths are true in all directions and representation is orthomorphic. A description of this projection is rather beyond the scope of this article; it is fully dealt with in chap. ii. of Germain's "Traité des Projections." The chosen meridian is 2° W., with the origin of co-ordinates in lat. 49° N. Co-ordinate distances in yards (eastings and northings) are given on the maps at 5,000-yard intervals, reckoned from a false origin (see Germain, *l.c.*, p. 45) 1,000,000 yards west and south of the above. The whole of Great Britain is to be transferred

ORDNANCE SURVEY (*Continued*)—

to this meridian in the new revision which is being compiled *de novo* from the 6-in. maps, the results of revision being incorporated in drawing. It is being reproduced by the photographic process. Maps on the 6-in. and larger scales are regularly revised every twenty years over most parts of the country, but Westmorland, Merioneth, Montgomery, Radnor, Brecknock, and Cardiganshire only once in forty years, and this applies also to most of the Scottish counties.

Index maps are published for all scales, those for the large-scale maps of the counties being on the ¼-in. scale and showing considerable detail.*

T. D.

ORGANIC—Concerned with organisms. Hence organic chemistry has become the term applied to the chemistry of the carbon compounds, of which the bodies of animals and plants are almost exclusively composed.

OXYGEN (Symbol O; atomic weight 16·00; atomic number 8)—A tasteless, inodorous gas, apparently colourless, but faintly blue when seen by light transmitted through a great thickness of it. The liquefied gas also is faintly blue. It makes up one-fifth part of the air we breathe and is extremely active, combining directly with most metals; hence the rusting and tarnishing to which these are liable. It supports all ordinary forms of combustion with great ease, and is, of course, most plentiful in combination, almost all substances in general use containing an appreciable amount of it. It is essential to the life of animals and plants, though the effects of deprivation of it appear much sooner in the former. The oxygen of the air contains a minute trace of ozone, a polymer of formula O_3, which is still more active than the element itself, but is very unstable and easily reconverted into oxygen. The health-giving effect of sea and country air has been ascribed to this trace of ozone, which is there more pronounced than in towns. What justification there may be for this is doubtful. (See Assimilation; Respiration.)

PALM NUT OR KERNEL—For composition, feeding, and manurial values see Feeding Stuffs.

PARAFFIN—A name of very varied connotation. To the chemist any hydrocarbon with an open carbon chain conforming to the formula $C_nH_{2n}+_2$ is a paraffin. Generally, in Great Britain, any burning oil or illuminating oil derived from petroleum is so designated. In America, and to some extent in this country, the final fraction of petroleum distillation, commonly called paraffin wax (see Waxes), is known as solid paraffin. Finally, it is claimed that the term "paraffin oil" is only strictly applicable to the burning oil fraction of the ultimate distillate from Scottish shale.

We shall follow a middle way, and at the same time one best suited to an agricultural work, by adopting the name for all burning oil

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* The writer is much indebted to the Director-General of the Ordnance Survey for information enabling him to bring this article up to date (July, 1930).

PARAFFIN (*Continued*)—

derived from petroleum. In the oil from Scottish shale, this is the middle fraction between mineral naphtha and light mineral oil. The corresponding fraction in the American trade is known as kerosene; it is heavier than petroleum benzine or benzoline, and lighter than lubricating oil consisting largely of hydrocarbons of the paraffin series from decane to hexadecane. The earlier fractions of the Russian oil are of burning oil character, as this petroleum contains a far smaller percentage of low boiling constituents; this burning oil is also of higher specific gravity, and contains a greater proportion of aromatic compounds (*i.e.*, compounds having benzene rings in their structure) than the American.

The old Roman lamp or lucerna in which vegetable oils were burned was a very shallow affair, as the wicks could not carry these oils to any great height. In this particular the introduction of the mineral burning oils was a great advantage. Flat wicks and lamp chimneys both serve to increase the temperature and so the luminosity of the flame. Lamps for oil burning should, for preference, be of metal, as then, when the oil in the reservoir falls, the wick holder becomes hotter and thus reduces the viscosity of the oil, enabling it to ascend more easily. Often the wick holder is prolonged down into the reservoir to aid this action, but such wick holders should not be used with oils of low flash point, or there is danger of explosion.

The illuminating power of a paraffin lamp normally goes down as the reservoir empties. This is due to the fact that the high boiling constituents of the oil tend to remain to the last, and these have not the illuminating power of the lighter boiling portions because, being more viscous, they rise less easily in the wick, causing charring.

Clearly, then, an illuminating oil is better the less of these high-boiling constituents it contains, but, on the other hand, it must not contain so much low-boiling material as to be dangerous. In Britain the minimum flash point permissible is 73° F., but all brands usually sold, except one from Roumania, fall appreciably above this limit.

The presence of large quantities of aromatic compounds in an oil makes it burn with a red smoky flame, but anything of the kind noted in a lamp supplied with any ordinary brand is more likely to be due to maladjustment of the wick or chimney.

Apart from its use as a burning oil, paraffin may be used in getting rust off metal-work, or in loosening rusted-up machine parts. For this purpose it has great penetrating power, but it should afterwards be replaced by a good lubricating oil, or the rust will reappear in even greater quantity as soon as an opportunity is given.

Of late years a type of refined paraffin has been used as an intestinal lubricant in medicine.

For its use in spraying as an insecticide see Insecticides and Fungicides.

PARSLEY—See Market Gardening.

PARSNIP—See Market Gardening.

PASTEURIZATION (of Milk)—See Milk; Milk and Milk Products, Bacteriology of; Milk, Provisions relating to the Production and Sale of.

PASTURE GRASS—For composition, feeding value, and conditions affecting the same, see Foods and Feeding, Scientific Aspects of; also Feeding Stuffs. Other features appear in Grasses, the Breeding of Herbage.

PEACH—See Stone Fruits, under Fruit.

PEA NUT—For composition and feeding value see Feeding Stuffs.

PEAR—See Hard Fruits, under Fruit; for methods of preservation by refrigeration see Refrigeration.

PEAS—Peas are supposed to be natives of Italy, where they grow wild; they have been found in Swiss lake dwellings of the Bronze Age, hence they have been cultivated for a very long time.

The pea belongs to the natural order Leguminosæ, and is an annual. The stems are trailing; the leaves are pinnate with two large fleshy stipules and one to three pairs of ovate leaflets; the leaf terminates in a tendril, usually branched, which winds round any available object and thus supports the plant.

The flowers are papilionaceous and self-fertile, and the fruit is a two-valved pod. It is usual to recognize two species of peas: (1) the field pea (*Pisum arvense* L.); (2) the garden pea (*Pisum sativum* L.).

The field pea has flowers with lavender-purple standard and rose-purple wing petals, whilst the garden pea has white flowers. The seeds of peas differ in size and colour according to the variety, while the length of the haulm is also variable. On germination the cotyledons remain permanently below the ground. As in the case of other leguminous plants, the roots possess nodules which contain symbiotic micro-organisms which ensure a supply of nitrogen for the growing plant. In consequence of this, healthy peas do not as a rule require large quantities of nitrogenous manure. Nodules apparently develop freely on the roots of peas in most soils, hence it is probable that the particular organism causing the nodule on pea roots is very generally distributed. The possibility of any benefit being derived from the inoculation of peas with cultivations of the organism does not appear to have been investigated in this country as far as the writer is aware.

Peas are grown as an agricultural crop, chiefly in the eastern counties. In 1929, Lincolnshire, with 28,317 acres, had the largest area, whilst Essex had 20,291 acres. The East and West Riding of Yorkshire had 13,128 acres, and Suffolk 12,362 acres. No other county had 7,000 acres.

Varieties—The very large number of garden peas in general use differ in length of haulm, character of seed, earliness, etc.; some of these have round seeds, and others wrinkled. Near large centres of population, varieties of garden peas are grown as a field crop, and the pods are picked green. Such varieties are, as a rule, more delicate than field peas, but in spite of this, they are frequently drilled in late autumn, usually November, in sheltered positions in mild localities.

PEAS (*Continued*)—

In a very severe winter they are usually killed by frost, but in a mild winter they survive, and being early, secure the first market, and consequently the highest prices. Some growers are willing to risk complete failure of crop on the chance of obtaining very high returns per acre occasionally.

It is outside the scope of this article to deal with the numerous varieties of garden peas, but the following white-flowering varieties, commonly grown as a field crop, may be mentioned. (See Peas, under Market Gardening.)

Harrison's Glory, a large blue pea with white flowers. This pea is more hardy than garden peas, but less hardy than field peas. It is very largely grown for packeting for use as a vegetable, the seed being harvested dry and thrashed, and subsequently hand picked. When garden peas are dear, these are often gathered green and used as green peas.

If the grain is badly harvested, or very much injured by grubs in the pods, it is utilized for stock feeding.

Prussian Blue is a small blue pea, grown for stock feeding, but is also suitable for splitting. Split peas have the skin removed and the two cotyledons separated; they are then sold for making soup, and years ago were much used for making pease pudding. An unnamed small white pea, also suited for splitting, is sometimes grown, and is favourably reported on. It is short in the straw, has white flowers and grain, and is early ripening.

The following field peas may be mentioned:

Early Minter or Norfolk Dun—An early ripening variety; straw medium length; pods fairly long; grain, a pure dun colour. Owing to its earliness it is less liable to Aphis attack than other kinds. Various strains selected for earliness, longer pods, or suitability for autumn sowing are offered by seedsmen. The earliness of this pea often enables the crop to be removed and the land ploughed before the bulk of the harvest is ready. This may be a great advantage, as it enables the land to be cleaned.

Maple or Partridge—This is a long-strawed pea, with numerous pods, the grain being light-brown, blotched irregularly with whitish yellow, and rather small in size. It is sometimes in good demand for pigeons.

This variety is late in ripening. It is better for smothering rubbish than short-strawed peas, but its lateness in ripening gives less opportunity for cleaning the land after it is removed. In a wet season it runs to straw, and may then give a poor yield of grain. In a normal year it yields fairly well, although probably not quite so well as certain other kinds.

Black-eyed Susan—This variety is common in the eastern counties, where it usually crops well. The straw is long and the grain large and dun-coloured with black eyes. It ripens in mid-season.

PEAS (*Continued*)—

Eights and Nines—Straw fairly long, pods long, the seeds being tightly packed in the pods and greenish in colour. Some growers strongly recommend this kind.

Comparatively little has been done by seedsmen and others, up to the present, in the improvement of field peas. Distinct varieties of field peas, Swedish Solo and Swedish Gold, have been introduced and tried in this country, but they do not appear to be superior to the ordinary English varieties.

A study of leading varieties of peas is now being made by the Plant Breeding Institute at Cambridge with a view to determining their suitability for canning and packeting, together with their utility as an ingredient of silage mixtures.

Climate—Peas, more than many farm crops, are greatly affected by the character of the season; probably the ideal conditions are moderate temperatures and rainfall. Very hot and dry weather in May and early June often results in an attack of Aphides, which, on light land, may spoil the crop completely. When this is the case the best plan is to fold the crop with sheep, or, alternatively, to put it into a silo and plough up and clean the land immediately. The plan of ensiling an Aphis-infected crop was found by one large grower some years ago to be thoroughly satisfactory, and the resulting silage was of excellent quality.

On heavy land a wet season causes the pea plant to turn yellow and produce practically nothing; especially is this the case with the more delicate varieties.

On more fertile land excessive moisture results in the production of too much haulm, especially in the case of normally long-strawed varieties, and under these conditions the yield of grain may be very small. Occasionally, in a wet year, the flowering season is greatly extended and the pods do not ripen. Here, again, probably the best method of dealing with the crop is either to fold with sheep or to ensile it. This may be done in a tower silo, or in a trench or shallow pit silo, 4 ft. deep and 12 to 14 ft. wide.

Suitable Soils—A good loam containing a sufficient supply of lime is usually considered to be the best type of soil for peas; on very rich soil there is a tendency towards over-production of haulm. A sufficient supply of lime in the soil is essential, and where the soil is sour the crop is very likely to prove a complete failure. This was very strikingly evident at Tunstall Experimental Station, Suffolk, in 1930, where peas drilled on a plot of land which had received chalk at the rate of 5 tons per acre, five years previously, yielded a very fair crop of 31 bushels per acre, whilst on an unchalked portion of the same field the crop was almost a failure, yielding only 8 bushels per acre.

Garden peas, particularly when autumn sown, are much more exacting in regard to soil and situation than field peas; for these a warm porous soil in a sheltered situation is essential.

Harrison's Glory will succeed on a considerable range of soils, whilst feeding peas will give fair crops on almost any soil provided it is neither

PEAS (*Continued*)—

waterlogged at any time nor lacking in lime. Heavy soil must be well drained if it is to be utilized for peas, otherwise in a wet season the crop is very likely to be a complete failure.

On really stiff soil it is desirable not only that it should be efficiently under-drained, but that after drilling, surface channels or water furrows should at once be made to conduct the water away in case of a heavy storm or during a spell of wet weather; neglect of this precaution may result in the failure of the crop over the whole or part of the field.

Position in Rotation—Peas are usually grown after a cereal crop. In the ordinary four-course rotation, peas alternate with beans and clover on the leguminous shift, hence it is easy to arrange that the peas are not grown on the land too frequently. This is found to be a wise precaution, as experience shows that it is better for peas not to be grown on the same land more frequently than once in eight years. Lisle, in "Observations in Husbandry," vol. i., p. 309, 1757, remarks, "Mr. Raymond says he has always observed that land which has carried peas one year will not be fit for them again in six years' time."

Peas may also be grown successfully after temporary pastures or rye-grass layers, and during the Great War it was found that on heavy land they were one of the most suitable crops to grow after broken-up permanent pasture. The grass land in such cases should be ploughed up before the new year, a skim coulter being used to bury the grass. In spring the land should be thoroughly consolidated by rolling, and repeatedly harrowed with light harrows before drilling. Apparently, peas are not very susceptible to attack by Wireworms, which are usually present in large numbers in old grass land, and are often responsible for the failure of other crops.

Peas will also succeed after other crops such as roots, potatoes, or members of the cabbage family, and where valuable sorts are being grown, it may be desirable to grow them after such crops, as the land is then clean and in good heart.

Manuring—Short-strawed and valuable varieties of peas may receive a dressing of farmyard manure, especially when they are autumn-drilled. With most varieties of peas, however, grown under normal soil conditions, farmyard manure is apt to encourage the formation of too much haulm. On really good land also, for the same reason, artificial manures are omitted, but where the land is not in first-class condition, it is better to apply some manure. If there is a shortage of lime in a soil, a dressing of that substance should be a first consideration. The quantity of lime applied varies according to the acidity of the soil; if slightly acid, 10 cwts. of quicklime or 1 ton of carbonate of lime will be beneficial, but if very acid, up to 2 tons of lime or 4 tons of the carbonate are necessary. Five tons of chalk per acre have given excellent results on acid soil (pH 5·8) at Tunstall in Suffolk, and where the land is near a source of chalk, it may be cheaper to apply the untreated material, rather than burnt lime or ground carbonate of lime.

PEAS (*Continued*)—

As peas obtain most of their nitrogen from the air, it is unlikely that nitrogenous manures can be profitably utilized except, perhaps, on short-strawed and valuable early varieties. Most artificial nitrogenous manures, and farmyard manure, tend to produce too much haulm, combined with a tendency to delayed ripening and poor fruiting.

On heavy land 4 cwts. of superphosphate (30 per cent.) or 6 cwts. of basic slag (or the equivalent of other qualities of these manures) per acre, may be applied, whilst on light land 2 cwts. of superphosphate and ¾ to 1 cwt. of muriate of potash per acre will be found useful. These manures should be applied before the land is harrowed down previous to drilling, but if slag is used it should be applied on the ploughing a month before drilling.

Cultivation—When the land is clean the cultivation necessary for peas is simple. The land is ploughed in autumn or early winter, and allowed to weather until it is proposed to drill the seed. If the land is not clean, every effort should be made to clean it immediately the previous crop is removed, and in a fine autumn much can be done in this way. The final ploughing should be given some time before seed time, for peas like a stale furrow, particularly on heavy land, and the weathering influences of the winter tend to produce a kindly seed bed, which is appreciated by peas, as by most crops.

As soon as the land is dry enough, if possible in January on light land, and in February or early March on heavy soil, it is worked down by harrows and the seed drilled at from 2½ to 4 bushels per acre, the quantity varying with the locality and with the variety of pea. The more delicate varieties should not be drilled too early on heavy land, as they are likely to suffer severely with cold, wet weather. Cases are known in which excellent crops of peas have been obtained on heavy land when they have been drilled as late as April. As noted previously, precautions should be taken to secure the rapid removal of surface water from heavy soils.

Field peas are usually drilled 9 to 12 ins. apart in the rows, the wider distance being used where the land is not very clean, as it facilitates the necessary horse-hoeing; garden peas are sometimes drilled at 18 or more inches apart in the rows.

As a rule peas should be horse-hoed when they are 2 or 3 ins. high, and subsequently hand-hoed. Hand-hoeing should be performed after horse-hoeing, but once the peas have become grown together, further cleaning is impossible. Peas should, indeed, never be grown upon foul land, as the open nature of the crop and their habit of lying down before harvest allows such weeds as docks, thistles, and goosefoot full access to light and air.

When peas are picked green, the crop may be cleared off and the land ploughed immediately, after which it may be sown with a catch crop of turnips or sheep feed.

Harvesting—There are several different methods of harvesting peas. Probably the best, but at the same time the most costly, is to

PEAS (*Continued*)—

get them up with a pea hook or "make," a tool (on the end of a shaft) somewhat resembling a sickle, but with a smaller curve in it. The pea hook is used to cut or break off the haulm of the peas close to the ground, and in the hands of a skilful man does good work. After cutting, the peas are rolled up into a small bundle or "wad." A scythe is used by some workers, and is considered satisfactory, but where labour is scarce or the work is urgent, the crop may be cut with an ordinary grass mower. The use of a reaping attachment to the mower, leaving the crop in heaps, somewhat facilitates harvesting operations.

When harvesting valuable peas it is probably best to use hand tools, but the mechanical methods mentioned above do quite satisfactory work if used with care.

After pulling, peas require turning by hand in two or three days' time, the ordinary hay fork being used for this purpose; this is repeated at intervals of a day or two until both straw and corn are thoroughly dry. In showery weather the peas must still be turned, or the pods on the under side will open. Valuable blue peas require turning practically every day, especially in sunny weather, or they lose their colour and become whitish, and then do not realize as high a price. When turning, the heaps of peas are thrown together to some extent; thus, when ready to cart, the crop is in rows, between which the harvesting waggon can pass. If the grain is slightly soft when carted, the crop should be put together in a narrow stack, placed in such a position as to secure the free access of wind; the grain will then improve very much in condition in the stack. In wet weather much difficulty and loss occurs in harvesting peas, and this is no doubt one of the reasons militating against increased cultivation. Much can be done to minimize this loss in enabling the peas to be carted at a slightly earlier stage than usual, by making narrow stacks in exposed situations and by constructing ventilating shafts through the body of the stacks.

Thrashing—This is performed in a similar way to that in practice with cereals, except that the crop, being loose, is fed into the machine with a fork. The concave of the thresher should be adjusted so as to avoid splitting the peas.

Value of Straw—Well-harvested pea straw is most useful for all kinds of cattle, but if damaged by weather it is useless except for litter; for some reason pea straw does not suit horses.

Mixtures of Peas with other Crops—Mixtures of peas and oats have been strongly recommended for making into hay. For this purpose a long-strawed variety of peas is desirable; such a mixture has also been found to be quite suitable for silage. (See Ensilage.)

Peas have often been mixed with spring beans, the crop being known as "blendings." For this purpose a fairly late variety of peas, such as Maple or Black-eyed Susan, should be chosen. A mixture of 2 bushels of spring beans and ¾ bushel of Maple peas was found to be a suitable seeding per acre at Saxmundham Experimental

PEAS (*Continued*)—

Station. An early variety of peas is also excellent for filling up a crop of winter beans damaged by frost.

(For composition and value of grain and straw for feeding see Feeding Stuffs; for insect pests see article at conclusion of Beans; for diseases see article at conclusion of Legumes, Breeding of Forage.)

A. W. O.

PEAT LAND—**Occurrence**—Vast areas of peat land occur in the northern parts of Europe and Asia, in Canada, in the United States of America, and in certain parts of South America and Africa. Probably the total area amounts to hundreds of millions of acres, for Europe alone is estimated to have over 100 million acres of peat land, the province of Ontario 22 million acres, and the state of Minnesota 7 million acres. The better utilization of such land is, therefore, a subject of great importance.

Peat formation occurs to the greatest extent in cold, humid climates, but it is by no means confined to these conditions, and can take place wherever the decomposition of plant remains is inhibited. Absence of air through water-logging, low temperature, acidity, and shortage of the nutrients necessary for the micro-organisms which cause the decomposition of plant remains are conditions which tend to bring about peat formation. Hence, peat is found most abundantly in cool, moist regions, especially where the land surface is flat or has hollows with poor drainage, and where the soil has a low content of chemical bases. Probably conditions were very suitable for peat formation during the period following the Ice Age, and peat is sometimes found at the present day under conditions which would no longer lead to its formation.

Classes of Peat Land—Owing to differences in the conditions under which it was formed and in the plants from which it was derived, peat varies greatly in general character and composition. In thickness it ranges from a fraction of an inch to 30 ft. or more. For practical purposes it is convenient to arrange peat lands in the following three main groups, but intermediate forms also occur:

1. *Heathland*—The peat is thin, rather dry, strongly acid, and usually with a considerable admixture of mineral matter. The substratum is frequently sandy or gravelly, and the dominant plants are heather, other members of the Ericaceæ, lichens, and mosses.

2. *Moorland*—There are many different varieties, but all are strongly acid, have a low content of mineral salts and a high moisture content.

3. *Fenland*—Deep peat relatively rich in mineral salts, alkaline or slightly acid in reaction, and frequently black and nearly structureless. It is much richer than the other two types in nitrogen, phosphoric acid, potash, and, particularly, in lime.

These groups are often further subdivided according to the plant associations found in them. (See Tansley's "Types of British Vegetation," Cambridge, 1911.)

General Character and Composition of Peat—Peat consists of partially decayed organic matter, together with varying proportions of

PEAT LAND (*Continued*)—

inorganic substances, and free and combined water. Freshly cut peat usually contains about 87-90 per cent. of water and 10-13 per cent. of solid matter. Owing to the presence of large amounts of colloidal substances, part of the water is very difficult to remove, and after air-drying 20-30 per cent. of moisture still remains. The organic matter consists of 57-61 per cent. of carbon, 5-6 per cent. of hydrogen, and 33-38 per cent. of oxygen. The amount of inorganic substance varies a great deal, but usually amounts to anything from 3-10 per cent. of the total solids. In some cases it is much higher, and in America this type of peat is often known as "muck." (See Soil Colloids and Humus.)

Peat also varies a great deal in colour, texture, and degree of decomposition. Well-decomposed peat is dark in colour, practically structureless, highly colloidal, and shrinks greatly on drying.

The average content of plant food in moorland, fen, and an intermediate type of peat is given by Professor Tacke as follows:

TABLE I.

PERCENTAGE IN DRY MATTER.

Type.	*Nitrogen.*	*Phosphoric Acid.*	*Potash.*	*Lime.*
Fen peat	2·50	0·25	0·10	2·50
Intermediate forms ..	2·00	0·20	0·10	1·00
Moorland peat	1·20	0·10	0·05	0·35

TABLE II.

POUNDS PER ACRE IN THE SURFACE 8 INCHES.

Type.	*Nitrogen.*	*Phosphoric Acid.*	*Potash.*	*Lime.*
Fen peat	10,704	1,070	267	17,840
Intermediate forms ..	7,136	624	178	3,568
Moorland peat	2,676	223	89	713

It is apparent from the above figures that peat soils, especially of the fen type, are very rich in nitrogen. All the types have a low content of phosphoric acid and potash, but the moorland type is particularly low in these constituents and in lime.

Reclamation—Methods of reclamation have been studied and practised in northern Europe (W. G. Ogg, *Scot. J. Agric.*, vol. xii., 1929), Canada, and the United States (F. J. Alway, Bull. 188, *Univ. Minnesota Expt. Stn.*, 1920) during recent years. This work has been carried out by the Governments of the various countries, by agricultural and forestry schools, by moor cultivation societies, by communities, and by private individuals.

It is particularly important in considering schemes of reclamation

PEAT LAND (*Continued*)—

to ascertain first of all to which of the three main groups—heath, moor, or fen—the peat belongs, since differences in thickness and composition of the peat, in its water relationships, and in the underlying material have a profound bearing on the method. The economic side of the question must also be kept in mind. In certain localities the value of the reclaimed land would not justify the expense of an elaborate reclamation scheme, but it might pay to improve the grazing by a simple system of open drains and the application of certain fertilizers.

There are two main systems of reclamation, viz., those involving the removal of the peat, and those in which the surface of the peat is cultivated. As they require very different treatments in regard to draining, cultivating, and manuring, it is convenient to consider the two systems separately.

Reclamation after Removal of the Peat—This system was widely practised in times when peat was used more extensively as fuel than it is at the present day. In its simplest form it is merely the cultivation of the underlying mineral soil, and the general principles of draining, cultivating, liming and manuring mineral soils may be followed. At first the fertility of such land tends to be low on account of lack of oxidation, absence of bacterial activity, and, where the peat has been completely removed, poverty in organic matter.

Under special circumstances, certain modifications of this system have been introduced. It is sometimes possible to flood the land systematically with mud-bearing water, and to obtain in this way a surface deposit of fertile material. This is known as warping (*q.v.*), and is practised extensively in Holland and to some extent in the east of England. In the neighbourhood of large towns the disposal of refuse is occasionally combined with the reclamation of peat land, a layer of refuse being spread on the surface after removal of the peat.

Complete removal of the peat results in a soil very poor in organic matter, and to obviate this some countries have regulations to the effect that when peat is removed the surface 20-24 ins. must be laid aside and replaced on the skinned land. The peaty layer is mixed with sand from the subsoil, manured, and cultivated. In practice the results of this system are very satisfactory, and it would be distinctly advantageous to apply such regulations wherever peat is being removed.

Cultivation of the Surface of the Peat—In most places coal has now superseded peat as fuel, and the bulk of the recent reclamation work has been carried out without removal of the peat. The first essential is, of course, good drainage, and the details of draining depend on the climate, composition and thickness of the peat, the configuration of the country, and, where the peat is thin, the nature of the underlying material.

Draining is usually carried out on deep peat by means of main drains, 5-7 ft. deep and about 100 yards apart, and secondary drains, 3 ft. 6 ins. to 4 ft. 6 ins. deep and 13 to 32 yards apart. Formerly

PEAT LAND (*Continued*)—

it was usual to leave the drains open, but now they are generally covered. The channel of the covered drains may be kept open by means of turf, heather, or brushwood, and drains of this kind are cheap but apt to become blocked. At the present day wooden boxes, or clay tiles laid on boards, are often used. The wooden box drains consist of four planks nailed together giving a channel of about 3 by 4 ins., and by means of wedges a slit is left to allow water to enter. The ends of the boxes are nailed together to prevent displacement, and boards are placed under the tile drains for the same purpose. It is a common practice to leave the trenches partially dug for a year to allow the sides to harden before completing the digging and laying of the drain. There is a possibility of over-drainage, for plant roots are unable to absorb water from peat soils when the water content falls below 60 per cent. by weight, and the best results are obtained when the peat is nearly saturated with moisture.

After the land has been drained it must be thoroughly cultivated, and this presents serious difficulties. On account of the insecure foothold afforded by the peat, cultivation by horse labour is difficult, and where horses are used they are often fitted with flat wooden shoes. Where tractors are employed they are provided generally with very wide wheels. In the first cultivation it is not easy to obtain a good tilth by means of a plough, on account of the tough character of the peat, especially where it is fibrous and undecomposed, and where the surface is uneven.

A machine has been devised recently which has done much to solve the problem of breaking-in peat land. It is on the rotary plough principle, and consists of a wide-wheeled tractor with an attachment containing a long shaft bearing knives or tines. The shaft is driven off the tractor, and by means of the knives the peat is chopped into small fragments. Two cultivations are usually necessary, the first to a depth of 8 ins. and the second to about 16 ins., and in this way the peat is thoroughly disintegrated and aerated. It is not considered advisable to use these machines too frequently for subsequent tillage, as the land would become infested with weeds, and too fine a tilth would be produced. Rolling by means of a roller weighing at least 1 ton per yard of width is also very necessary in peat cultivation.

It was formerly a common practice to burn the surface of the peat every few years, but after a time this treatment renders the land almost totally unproductive. The application of heavy dressings of sand or clay to the surface was also common formerly, but at the present time, on account of the high cost of labour, it is seldom attempted.

In the reclamation of the acid types of peat land it is usual to apply lime. The amount naturally depends on the type of peat, and on the purpose to which it is to be put, but dressings of ½ ton to 2 tons of burnt lime, or equivalent quantities of ground limestone or shell sand, are usual. Very heavy liming may be actually detrimental. (See Lime and Liming.)

PEAT LAND

To obtain the best results from peat land, fairly heavy applications of manures are necessary. Peat is particularly poor in phosphoric acid and potash, and for the first two years dressings of 1 to 1¾ cwts. P_2O_5, equivalent to 7 to 12½ cwts. basic slag, and 1¼ to 1¾ cwts. K_2O, equivalent to 2½ to 3½ cwts. muriate of potash, per acre per annum are usually necessary. These amounts may be reduced later. Peat soils contain a considerable amount of nitrogen, but, especially in the case of moor and heath types, it may be largely in a form not readily available to plants. It is desirable, therefore, to apply to these types dressings of ½ cwt. of nitrogen, equivalent to 2½ cwts. sulphate of ammonia, per acre, for the first few years. The application of farmyard manure is very beneficial, as it promotes bacterial activity in addition to supplying plant food.

Crops—A considerable range of crops can be grown on peat land, the commonest being oats, rye, potatoes, six-rowed barley, turnips, various legumes, and grasses. When leguminous crops are being grown for the first time, it may be necessary either to inoculate the peat with soil from a field where legumes have been grown, or to inoculate the seed with cultures of appropriate bacteria. There is a tendency to concentrate on hay and pasture in northerly districts, where it is difficult to ripen cereals, and mixtures consisting of smooth-stalked meadow-grass, timothy, meadow fescue, foxtail, white clover, and sometimes perennial rye-grass, have been found most suitable.

Market garden crops, such as onions, cabbage, carrots, lettuce, celery, beets, parsnip, and spinach, can also be grown very successfully, and are said to be of particularly good quality. Cranberries, blueberries, and certain ornamental trees and shrubs do well in certain districts.

Crops grown on peat land are apt to suffer from summer frosts, and one of the principal lines of research is the selection of hardy and early ripening varieties. As moorland and heath soils have a high degree of acidity, it is also important to cultivate varieties able to withstand this soil condition. Another common trouble is "lodging" in cereals, and attempts are being made to obtain varieties with stronger straw. (See Oats.)

There are several diseases particularly prevalent in crops grown on peat soils. Cereals and grasses, for example, suffer from rusts, and research is being conducted with a view to evolving resistant strains. There are also various diseases said to be physiological, some of which are produced by over-liming; treatments with manganese sulphate, copper sulphate, ammonium sulphate, and farmyard manure have all been found effective in modifying these conditions. Eriksson mentions certain varieties of oats apparently very resistant to the disease known as "Grey Spot," which is supposed to be connected with an excess of lime in the soil solution (Eriksson, "Fungus Diseases of Plants," Baillière, Tindall and Cox, London, 1930). (See also Diseases of Cereals, under Wheat.)

Modern methods of cultivation and the use of suitable manures

PEAT LAND (*Continued*)—
and crops have recently brought about vast improvements in peat cultivation, and if drainage costs could be reduced, there appears to be no reason why great areas of this type of land should not be improved or reclaimed.

The Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen—Although there are great areas of peat land in the British Empire, the scientific study of its improvement and reclamation has been almost entirely neglected.

Through the generosity of a Canadian, Mr. T. B. Macaulay, of Montreal, this has now been remedied, and a national soil research station for Scotland has been established (1930), which will devote special attention to peat soils. Laboratories, facilities for pot culture work, and experimental grounds have been provided at Craigiebuckler, on the outskirts of Aberdeen, and a demonstration farm on peat land is being developed on Arnish Moor in the island of Lewis. An area of 147 acres was acquired, consisting partly of shallow peat of the heath type, and partly of very wet moorland with deep peat. This is being drained, cultivated by means of a rotary tiller, and developed as a dairy farm. Good pasture has been obtained, and experiments are being conducted on methods of draining, cultivation, manuring, and cropping.

REFERENCES TO LITERATURE—On the agricultural side the most important European publications are the Bulletins and Journals of the following: *Swedish Peat Society* (Jönköping), *Danish Heath Society* (Viborg), *German Moor Experiment Station* (Bremen), *Society for the Promotion of Moor Cultivation in Germany* (Berlin), *Bavarian State Institute for Moor Cultivation* (Munich), *Norwegian Peat Society* (Oslo), *Russian Central Peat Station* (Moscow), *Finnish Peat Cultivation Society* (Helsingfors).

Amongst the publications dealing with American and Canadian work are: Bulletins of the *Agricultural Experiment Station, University of Minnesota*, of the *U.S. Department of Agriculture* (Washington, D.C.), and of the *Ontario Agricultural College* (Guelph). References to agricultural development are also made in the publications of the following: *British Fuel Research Board, Canadian Department of Mines, Ontario Bureau of Mines, U.S. Geological Survey, Geological Survey of Ohio.*

W. G. O.

PEPPER—The dried fruit of a tropical plant, *Piper nigrum* (*Piperaceæ*). When the berries, which grow in a spike, are ripe, they are red, but on drying after plucking in the half-ripe state they become black, and the product is sold as black pepper. When the outer skin is removed from the ripe fruit, white pepper is obtained. Red or cayenne pepper is the ground fruit of various species of *Capsicum*, and was first brought to Europe by Chanca, the physician who sailed with Columbus. The smaller fruits are more pungent than the larger. The pungent principle is actually situated in the placentæ, but other parts of the fruit acquire

PEPPER (*Continued*)—

it by contact. So powerful are some red peppers that in preparation they have to be handled with gloves, or the hands become badly burned.

PEPPERMINT (*Mentha piperita*)—This perennial plant, a native of England, is the source of the oil of peppermint of commerce, and although large quantities of the oil are imported from America and the Continent, several hundred acres are grown annually in Great Britain. Where proper care is bestowed on it, the crop can be very profitable. The oil, which is very volatile, is obtained by the distillation of the stems and leaves of the plants when fully grown, and when embarking on the cultivation of this crop on a large scale, it is primarily necessary for a grower to erect a still on his own premises. Several firms specialize in essential oil stills, and the grower needs only to estimate the size necessary for dealing with the crop he intends to produce.

A modern peppermint still is an expensive installation, ranging in price from £300 to £500 according to size, and smaller growers in the peppermint-growing districts usually make arrangements with the owners of local distilleries for the distillation of their crops, selling the oil to these firms or marketing it themselves according to choice.

Cultivation—Peppermint does best in deep, loamy soils which retain the moisture, and in common with most of the Labiatæ it favours the calcareous loams, provided they are not too shallow and too prone to drying out. Atmospheric conditions are important from the point of view of the yield of oil, and the maximum amount of sunshine is necessary while the crop is growing. For this reason most of the peppermint-growing areas of England are located in the eastern and south-eastern counties.

As the crop will occupy the same piece of land and yield profitable crops without disturbance for several years, the thorough preparation of the land prior to planting is very important. It should be ploughed and subsoiled, and from twenty to thirty loads of farmyard manure to the acre should be applied. Just before planting, 5 cwts. of superphosphate and 2 cwts. of sulphate of potash should be cultivated in. Potash has been found to strengthen the growth and assist the crop in resisting attacks of Rust (*Puccinia menthæ*), besides substantially increasing the yield of oil. Experiments have shown that it will pay growers to give an annual application of from 2 to 3 cwts. of sulphate of potash in early spring.

There are two methods of growing the crop: one method is to set the land out in beds from 6 to 10 ft. wide with separating alleyways of about 3 ft. between. The plants are planted in the beds in rows 9 ins. or 1 ft. apart with 9 ins. between the plants, and each winter the thick fleshy rootstocks, or runners, which come to the surface, are covered with about 2 ins. of soil taken from the alleyways. This method has its advantages, as it facilitates weeding and cutting.

The other method is to plant the field regularly all over on the flat, and give it a shallow ploughing over each winter to bury the

PEPPERMINT (*Continued*)—

runners. The two small advantages of the latter method are that the ploughing cuts up the runners into small pieces, so propagating the crop, and it is possible to reap the crop with a machine instead of by hand with sickles, as is necessary in the case of the bed system.

Planting is carried out by means of the "suckers" which arise from the rootstocks each spring. These may be bought in ready for planting out, or the grower may purchase a supply of runners during the autumn or winter and make up his own nursery bed to supply the suckers. It is estimated that 42,000 plants are required to plant an acre.

Harvesting—The peppermint crop is usually ready for harvesting towards the end of August before the leaves begin to fall and just as the plants are coming into flower; the oil content of the plants is then at its maximum. After cutting, it is usual to let the crop lie on the ground to wilt partially. Getting rid of the moisture in this way will not affect the oil content, but will enable the grower to bale up the crop in mats to await carting to the still. In the case of large areas of peppermint, it will take several weeks to distil the whole of the crop, hence the necessity for the partial drying and baling described.

The technical points of essential oil distillation need not be gone into here. Peppermint stills should be steam boiled, and charges of from 5 to 20 cwts. are the usual rule. The oil run usually commences in about half an hour, and complete distillation takes about six hours. Where the crops are large, it is usually necessary to run the stills both night and day in order to deal with them. The yield of oil will vary according to the weather conditions, age of the planting, etc., but in England the average yield is from 30 to 40 lbs. per acre. The price of the peppermint oil tends to fluctuate, and it is the usual practice to retain the oil in store against propitious times of selling. It should be stored in blue Winchesters in a cool, dark place which is not subject to a wide range of temperature; for these reasons oil stores are usually constructed of concrete, and partially, or wholly, underground.

PERRY—Pears for manufacture of, see Pears, under Fruit.

PHOSPHORUS (Symbol P; atomic weight 31·027; atomic number 15)—This element, which is of the highest importance in combination both to animals and plants, exists in two allotropic modifications—namely, white (or yellow) phosphorus, a waxy, slightly yellow, almost transparent solid, which is so inflammable that the mere operation of cutting it in air will often cause it to ignite; and red phosphorus, which is not at all dangerous if handled with care. The white form is virulently poisonous, while the red is not. The molecule consists of four atoms in both cases. In the combined form it occurs as calcium phosphate in the seeds of plants and in soils, also in the bones of animals. Sodium phosphates are of importance in the maintenance of the pH of the blood. (See Sodium and its Compounds, Acid.) A proper supply of phosphorus in the soil is of great importance to all

PHOSPHORUS (*Continued*)—
kinds of crops. (See E. Vanstone, *J. Soc. Ch. Ind.*, 45, 78T. Consult also articles Acid; Fertilizers; Manuring, Principles of.)

PINEAPPLES—For methods of preservation by refrigeration, see Refrigeration.

PLANT DISEASES—For diseases of cereals see article at conclusion of Wheat; for diseases of forage crops see article at conclusion of Legumes, Breeding of Forage; for diseases of glasshouse crops see Glasshouse Crops; for diseases of hops see Hops; for diseases of potatoes see Potato; for diseases of vegetables see individual vegetables under Market Gardening. See also Seed, Transmission of Plant Diseases by; Plant Diseases and Pests, Legislation with Reference to; Plants, Disease in Resistance to; Virus Diseases.

PLANT DISEASES AND PESTS, LEGISLATION WITH REFERENCE TO—Few of the many plant diseases and pests known to exist have yet spread throughout their potential geographical range; thus there are numerous insects or fungi which occur in America or Japan, but which have not yet established themselves in Europe, although there can be little doubt that many of them would do so if given the opportunity. The reason for this state of affairs is that few insects or fungi are able by natural means to cross wide stretches of ocean, high mountain ranges, deserts, or other tracts of land unsuited to their existence, and it is only by taking advantage of the means of transport provided by man that these natural barriers can be crossed. In this connection it is obvious that the conditions most favourable to such transport are provided by the international exchange of living plants, tubers, roots, etc., because then the insect or fungus can travel on its natural host plant, which provides ample food on the journey; in this way the *Phylloxera* of the vine was brought to Europe on vines from America, the European Narcissus Flies have been carried to America on bulbs from Europe, while the Codling Moth of the apple has now attained an almost world-wide distribution, having been taken from one country to another with apples. Very many instances such as these could be quoted, and they would show that as a rule the imported insect or fungus has caused very serious losses; it is, indeed, a remarkable fact that when a pest or disease is newly established in a country which it has not previously inhabited, it often becomes epidemic, and causes far more damage than it was known to do in its old home—Potato Blight and American Gooseberry Mildew are familiar instances in Britain, while the Gipsy Moth, the European Corn Borer, and a host of others testify to the same fact in America. It is therefore natural that practically every civilized country in the world now makes some attempt to close its frontiers to these undesirable immigrants, and with this end in view has passed laws to regulate the importation from abroad of living plants, tubers, etc., which, as just pointed out, present the greatest risk of introducing diseases or pests. As a natural corollary to such action, most countries have also taken powers to deal with diseases and pests which have passed the frontier, but which may still

PLANT DISEASES AND PESTS (*Continued*)—

be eradicated or confined to a limited territory. Legislative measures for dealing with plant diseases and pests may thus be classified into: I. External Measures, designed to prevent the introduction from abroad of plant diseases and pests; and II. Internal Measures, for dealing with diseases and pests which may have already become established.

I. **External Measures**—The measures which can be taken to exclude diseases or pests from any country include (*a*) an embargo on the classes of goods likely to carry such pests or diseases; (*b*) the placing in quarantine or the disinfection of the merchandise in question; (*c*) the examination of the merchandise on arrival; and/or the requirement that it be accompanied by a certificate of health. A country may of course limit itself to one or other of these measures, but not infrequently all are made use of, the various categories of imports being treated differently.

(*a*) The most drastic measure, the embargo, is clearly the most effective in preventing the introduction of pests and diseases, but it has also the serious disadvantage of closing international trade in the direction concerned. Its use in practice is thus limited to categories of imports which are not essential to the country in question. When, for instance, a country is growing sufficient potatoes to provide an ample supply for the entire population, it can consider placing an embargo on potatoes from elsewhere if it is believed that such a course would prevent the introduction of serious diseases or pests, whereas if the home supply is deficient the embargo is at once put out of court. It is therefore natural to find that countries which have an ample sufficiency or an exportable surplus of agricultural or plantation products tend to favour the embargo in so far as the plants responsible for these products are concerned.

(*b*) The placing in quarantine or disinfection of plant imports is rather less drastic than the embargo, but except in special cases it greatly restricts international trade. If a consignment has to be kept in quarantine at a Government Station, or if it has to be subjected to fumigation with hydrocyanic acid gas or some other fumigant, the trade tends to become confined to small consignments of new varieties, usually of considerable value—that is to say, to plants for propagation before being distributed to the general public. There are of course exceptions to this rule when the particular category of import concerned can be easily disinfected at an economic cost. As regards effectiveness, the quarantine properly carried out (which ordinarily involves the growth of the plants for a season in quarantine) can practically equal that of the embargo. Disinfection, on the other hand, has a more restricted value; if properly carried out it can be very effective against a certain limited number of pests or diseases which are subject to this form of treatment, but too often it is regarded as a "cure-all," regardless of the fact that no known treatment or treatments will infallibly destroy all pests and diseases: it then merely gives a sense of security which is wholly false.

(*c*) The examination of plant imports or the requirement that they

PLANT DISEASES AND PESTS (*Continued*)—

be accompanied by a certificate of health is the least drastic measure which can be employed; it allows international trade to be carried on without serious curtailment, although perhaps at the expense of some irritation to the parties concerned. The consignments of imported plants may be, and often are, examined by inspectors at the port of destination, but it is usual also to demand a certificate of health given after examination by the officers of the phytopathological service of the exporting country. Theoretically the system is subject to certain grave disabilities, chief of which is the impossibility of detecting all pests and diseases by examination, but in practice rather better results are obtained than might be expected, especially where the exporting country is willing to take the matter seriously, which is not always the case. Assuming, however, both the will and the ability to do the work of examination properly, the health certificate system, backed up by a reinspection of the plants on arrival in the country of destination, will ensure that the consignments arriving are at least of a very high standard of health, and will not result in any mass introduction of serious pests, which latter is in itself a very considerable safeguard.

Comparing the merits of the three systems, it has already been pointed out that their relative efficiency varies in accordance with the extent to which they interfere with trade, the most efficient method causing the greatest interference and *vice versa.* This interference with trade is particularly unfortunate in that it encourages sections of the public to regard plant protection regulations as merely alternative to a tariff. There is thus a section in the importing country financially interested in obtaining an embargo regardless of the real danger from the disease standpoint, while there is also another section in the exporting country equally interested financially in preventing the embargo, again without much regard to the standard of health of their exports, and the case may then fail to receive proper consideration upon its scientific merits. From time to time there have been attempts to arrive at an international convention which would overcome this difficulty, notably by encouraging the adoption of the health certificate system, as, for instance, the Rome Conventions of 1914 and 1929, but up to the present no formula generally acceptable has been devised.

A final point which needs emphasis in connection with external regulations is that none, even the embargo system, is more than partially effective. As the distance in point of time between one part of the world and another lessens, so it becomes easier for a pest to travel without its food plant, and with the development of air transport such possibilities are greatly increased. No import regulations can possibly deal with these casual travellers, and therefore success in preventing the establishment of new pests and diseases depends not only on external regulations, but also on an efficient intelligence service which will detect outbreaks of new pests when still on so small a scale as to admit of immediate and complete eradication.

II. **Internal Measures**—Internal measures are, in the first place, concerned with the attempted eradication of some new pest or disease

PLANT DISEASES AND PESTS (*Continued*)—

which has effected a lodgement; if this fails, then the next step is usually an attempt to confine the disease or pest to a limited territory; finally, compulsory measures are not infrequently demanded even in the case of diseases or pests which have become widely spread and may be native to a country, the demand arising when neglect on the part of one occupier adversely affects others.

(*a*) *Measures of Eradication*—Since the precise measures are determined entirely by the nature of the pest or disease in question, few generalizations on the subject can be made. As has already been indicated, the point of greatest importance is to detect the outbreak when it is in its earliest stages and is still confined to a small area, for drastic measures can then be employed which would be out of the question in the case of large districts; no less important is the intelligence service after the first outbreak has been signalled, since it is vital that any subsidiary outbreaks should be detected at once. Thus, the outbreaks of the Colorado Beetle in England in 1901 and in Germany in 1877, 1887, and 1914 were detected when still on a very small scale, and the pest was completely wiped out; whereas in France it probably existed for nearly two years before discovery, and up to the present all efforts to eradicate it have failed. Indeed, in general, it may be said that it is almost hopeless to attempt to eradicate a pest or disease which has colonized more than a few square miles before detection, the one possible exception to this statement being the apparent success of the American campaign against the Mediterranean Fruit Fly in Florida.

(*b*) Measures for confining a disease or pest to a given territory follow in principle those employed in excluding it from a country as a whole, and they similarly comprise embargoes, quarantines, etc. In the majority of cases the attempt must be foredoomed to ultimate failure, but it is often justifiable nevertheless—in the first place, to gain time in which to work out suitable control measures and to import natural enemies (insect parasites, etc.), and secondly to protect areas which are vitally concerned in an export trade. Many countries, for instance, place an embargo on potatoes coming from areas known to be infested by Wart Disease, and it is thus important in the interests of the export trade to preserve districts free from the disease, although there is no prospect whatever of eradicating it from the country as a whole.

(*c*) With the establishment of the principle that it is justifiable to adopt compulsory measures to protect a "clean" area from one infected by some disease or pest, it is merely an extension of the same principle to require a single owner or occupier of land to adopt measures of control in the interests of his neighbours. Under such circumstances the methods of control which may be enforced include in theory all those which have been proved effective under normal conditions—spraying, pruning, the use of special seed, and so forth—but in practice compulsory measures should be confined to those which can be easily enforced. The administration of legislation requiring a grower to plant only certain varieties of a crop, or to remove all dead trees, for instance,

PLANT DISEASES AND PESTS (*Continued*)—

can be properly enforced, but it is clearly more difficult to compel a grower to spray satisfactorily: he can be compelled to spray, of course, but it is less easy to ensure that the standard of performance is adequate, and unless he does the work well the treatment may be useless. In some countries this difficulty is overcome by giving the authorities power to do the work through their own officers, and to recover the cost from the occupier, but this alternative does not always exist. Apart from the difficulty of choosing measures which can be easily enforced, action against pests and diseases of purely local significance is apt to engender opposition on account of a not unnatural objection to interference by the central Government in local affairs, and this type of action is therefore, perhaps, better left to local authorities or to growers' organizations which can sometimes enforce measures of a far more drastic character than could be considered by the central Government.

The above account deals briefly with the broad principles upon which legislation dealing with plant diseases and pests is based. Owing to the rapidity with which the situation changes, it would be useless to give any account of the precise laws and orders in force at the time of writing, and for information in regard to them readers should apply to the Ministry or Department of Agriculture of the country in which they reside.

J. C. F. F.

PLANTS, DISEASE IN, RESISTANCE TO—The chief methods used in the control of plant disease are spraying and seed treatment, and various hygienic measures for the elimination of sources of infection. (See Insecticides and Fungicides; and Seed, Transmission of Plant Diseases by.) These processes are expensive, for they must be carried out regularly and, if the need for them could be done away with by the growing of plants which do not take disease, a heavy annual toll would be saved. Such resistant varieties of plants are known, and typical examples are given below which show that this quality of disease resistance is widespread and relates to various parasites.

Disease.	*Resistant Varieties.*	*Susceptible Varieties.*
Potato Blight	**Evergood, President, Champion II.**	**Up-to-date** and most other varieties.
Potato Wart Disease..	**Great Scot, Majestic.**	**King Edward, Arran Chief.**
Tomato Sleepy Disease	**Manx Marvel, Bide's Recruit**	Most varieties.
Apple Canker	**Newton Wonder, Bramley's Seedling, Blenheim Orange**	**Cox's Orange Pippin, Lord Suffield, Worcester Pearmain.**
Plum Silver Leaf ..	**Pershore, Greengage**	**Victoria, Czar.**
Plum (*Fomes pomaceus*)	**Victoria**	**Pershore.**
Cherry Leaf Scorch ..	**Turk, Crown**	**Florence, Waterloo.**
Wheat Foot Rot ..	**Kanred**	**Marquis, Red Durum.**
Rose Mildew	**Gloire de Dijon**	**Dorothy Perkins, Crimson Rambler.**
Hyacinth Yellows ..	**Robert Steiger, Grand Maître**	**Zar Peter, La Neige.**

PLANTS, DISEASE IN, RESISTANCE TO (*Continued*)—

Plants often appear to resist disease when they are merely susceptible varieties growing under conditions in which they escape infection. On the other hand, there are truly resistant varieties, but, as will be shown below, this quality of resistance is not a simple matter.

The germ tubes of fungus spores seem to penetrate the skin of the plant they attack merely by pressure, and so one would expect thick-skinned, hairy, or waxy plants to remain healthy. There is, however, little evidence that, in general, this is the case, although the Rust fungus (*Puccinia graminis*) can only attack young thin-skinned barberry leaves; the comparative resistance of certain plums to Brown Rot (*Sclerotinia cinerea*) is apparently due to the toughness of their skins and the firmness of their flesh, whilst the greater resistance of older as compared with younger rye plants to *Fusarium nivale* seems to be related to the higher cellulose and silica content of old cell walls.

There are, however, easier ways into a plant than direct penetration, and many fungi and bacteria enter by way of the stomata. In the case of the sugar beet, plants or leaves with small or protected stomata are comparatively resistant to Leaf Spot disease (*Cercospora beticola*), and potato tubers with corky lenticels are not easily infected by *Phytophthora*, which seems unable to penetrate this barrier.

The reaction of certain varieties to disease is apparently correlated with the internal structure of the plants. Thus Webster wheat is able to resist *Puccinia graminis* because of its abundant sclerenchyma which checks the growth of the fungus in the tissues. Also if wheat and maize are grown at unfavourable temperatures they develop thin, abnormal walls which render the plants more susceptible to seedling blights.

In certain Rust-resistant varieties of wheat the fungus enters the leaves and kills the adjacent host cells, but is then itself killed by toxic substances which diffuse out from these dead cells. Resistant wheats may, therefore, be regarded as, really, hypersensitive to the parasite, the rapid death of the tissues isolating the fungus from its living food supply by a barrier of dead cells. In susceptible varieties the invaded cells are, apparently, stimulated to produce an increased food supply for the fungus. If Rust spores are put on to a wrong host they germinate and penetrate a little way, but then die out.

There is a certain amount of evidence in support of the common view that highly coloured varieties of plants are more resistant to disease than uncoloured varieties. Beans with red or mottled seeds are less susceptible to Rust (*Uromyces appendiculatus*) than white varieties; antirrhinums with red pigment in their shoots are comparatively resistant to attack by the fungus *Heteropatella antirrhini*, and red and yellow skinned onions are very resistant to Onion Smudge (*Colletotrichum circinans*), whereas white-skinned varieties are susceptible. In the latter example it has been shown that resistance is dependent upon certain substances associated with the pigments and also volatile oils and associated non-volatile substances in the cell sap. It has often been suggested that the osmotic pressure of the host, the acidity of the cell sap, or the presence in the tissues of particular

PLANTS, DISEASE IN, RESISTANCE TO (*Continued*)—

chemical substances might influence disease resistance, but no good evidence of this is yet available.

Although resistance and susceptibility to disease are innate qualities, their degree is usually modifiable within wide limits by variations in environmental conditions. In no case does there seem to be absolute immunity to disease quite irrespective of external conditions. Wart-immune potatoes, which were once thought to show this definite quality, have in certain cases manifested a slight degree of susceptibility under severe conditions of infection.

The environment may so influence the structure of a plant or its physiological condition that its normal reaction to fungus or bacterial attack is changed. Sometimes this effect seems to be climatic, as in the case of the Australian Rust-resistant wheat Bobs, which remained resistant at Pretoria but was susceptible when grown in low-lying ground in South Africa. Similarly, Einkorn wheat, which under ordinary conditions is almost immune to Black Rust, becomes severely affected in the Ganges Valley during the hot May weather. Early sown wheat is more attacked by the fungus *Helminthosporium* than late sown wheat, whereas very early or very late sown winter wheat is freer from Bunt (*Tilletia caries*) than wheat sown intermediately. The apple variety Yates is highly resistant to Scab (*Venturia inæqualis*) in Otago and susceptible at Nelson, but this may not be climatic, but merely due to the presence of a different strain of the parasite.

Marked effects are often brought about by food supply and the nature of the soil, but in such cases it is not easy to distinguish the effect on the innate quality of the host and the effect on the visible appearance of the disease due to the altered size and growth of the host plant. Varieties of wheat, for example, normally resistant to Yellow Rust (*Puccinia glumarum*), often break down under heavy nitrogenous manuring, but some of this effect is undoubtedly due to the increased size and bulk of the plants, which gives the parasite more opportunity to develop. In general, however, heavy nitrogenous manuring of most crops tends to increase liability to disease, whilst application of potash and phosphate tends to decrease liability. Phosphate in particular usually leads to a more rapid maturation of the plant, and the indirect effect on its disease reaction may be profound. It is not, however, safe to generalize. In the case of the tomato, for example, soft nitrogenous plants are more resistant to attack by the fungus *Verticillium*, whilst application of superphosphate increases liability to attack by *Sclerotinia libertiana*. Either potash or nitrogen manuring of gooseberries seems to increase liability to *Botrytis* disease. Potash manuring of apples seems to increase resistance to Mildew and decrease it to Scab. Beets and mangolds are more liable to attack by *Phoma betæ* when growing on markedly alkaline soils, whereas turnips and cabbages suffer more from Finger-and-Toe (*Plasmodiophora brassicæ*) on acid soils. On heavy wet soils apple varieties normally resistant to canker (*Nectria galligena*) may become seriously diseased. (See Glasshouse Crops; and Fruit Plants, Manuring of.)

PLANTS, DISEASE IN, RESISTANCE TO (*Continued*)—

It is often possible to change the environmental conditions in such a way as to enable the plants to withstand parasitic attack, but, in all such cases, it is not easy to decide whether the result is due to an effect on the host or on the fungus. In fact, it is usually difficult to distinguish between innate resistance to disease and the presence of qualities or conditions enabling a susceptible plant to escape disease. Following a dry spring a susceptible apple may be free from disease, whereas after a wet spring and early summer it may be badly scabbed. Early potatoes may escape blight, as may also main crop varieties which have quickly drying leaves, although both may be completely susceptible to *Phytophthora*. The raspberry varieties least damaged by *Coniothyrium* are those with a waxy surface from which water easily drains. Barleys with close ears which keep the flowers entirely shut in during fertilization are more rarely attacked by Loose Smut (*Ustilago nuda*) than barleys with open flowers, although both kinds are, in reality, equally susceptible to disease.

Many plants escape disease by forming protective tissues such as layers of cork across a wounded surface. This is well known in the case of the potato tuber, but in many other plants such an impenetrable barrier is formed just in advance of the invading fungus, whose further attack is thus prevented. In this way resistant strains of flax wall off the fungus *Fusarium lini* in their stems, and larch and apple trees check Canker-forming fungi. Sometimes the fungus may be entirely occluded, but during wet or cold seasons it may evade the cork barrier and extend the canker. In the case of Silver Leaf disease of plums (*Stereum purpureum*) resistant varieties, such as Pershore, form gum which prevents the fungus developing, and, in a very good growing season, even such a susceptible variety as Victoria may, on occasion, succeed in gumming off the parasite.

Speaking generally, the innate quality of resistance to disease is usually a specific localized thing. For example, a tuber of a potato resistant to Wart disease (*Synchytrium endobioticum*) remains resistant even when it is grafted on to a stolon of a susceptible variety from which it receives all its food; conversely a tuber of a susceptible variety remains susceptible even when grafted on to an immune plant. Grafting of plant parts does not usually influence the disease reaction of the parts, but in certain cases such an alteration does seem to occur. Lord Derby scions render the stock more susceptible to Crown Gall (*Bacterium tumefaciens*), and Bramley's Seedling render the stock more resistant. Bramley's Seedling is usually very resistant to Canker, but, grafted on French Paradise II., it becomes highly susceptible. On the other hand, in combating numerous root and collar diseases a desirable but susceptible scion is grafted on to a resistant stock, and the disease thus avoided; a method used very successfully for apples and pears and for vines against attack by the insect *Phylloxera*.

Many parasitic fungi and bacteria exist as numerous strains which have different powers of causing disease and which, also, may not have the same geographic distribution. This has, in certain cases, allowed

PLANTS, DISEASE IN, RESISTANCE TO (*Continued*)—

of the introduction to a region of new varieties of crop plants resistant to the local strains, and it may also explain many cases of altered disease reaction which are usually attributed to climatic and other factors or to the degeneration or running out of crops.

The great majority of disease-resistant varieties have been obtained by the continued selection for seed purposes of individual plants (as for Cabbage Yellows) or of varieties (as for Wart disease of potatoes) which have been found to resist disease under conditions in which the parasite has had the most favourable chances of attack. Such selections are then purified by artificial self-pollination, and multiplied for commercial supply.

It is sometimes possible to cross a resistant strain otherwise worthless with a susceptible strain possessing desirable qualities. In this way wheats resistant to Rust, hops resistant to Mildew, and other valuable crop plants have been synthesized. Genetically, resistance to disease is in many cases a simple unit character, although in other cases, *e.g.*, Wart disease of potatoes, the situation is more complex. As might be expected from what has been said of the nature of disease resistance, there is no uniform rule governing its inheritance in plants, and there are many difficulties in the way of breeding for disease resistance. Resistance to disease is not usually associated with other desirable agricultural qualities, and a variety immune to one disease may be highly susceptible to another, as the Victoria plum, which is almost immune to attack by *Fomes pomaceus*, but extremely susceptible to *Stereum purpureum*. Furthermore, the resistance of a variety to one disease may be destroyed by the attack of another parasite, as in the case of Little Joss wheat, which is normally resistant to Yellow Rust, but which succumbs to it when attacked by Bunt. As already mentioned there are, very often, biological strains of the same parasite, and a crop variety resistant to one strain may be susceptible to another. Further, these strains may not remain constant, but may, on occasion, give rise to new strains capable of attacking previously resistant varieties. The securing of resistant varieties by breeding is therefore a somewhat hazardous process, but in spite of its laboriousness and uncertainty it is a very hopeful line of work. Hybridization and selection methods are often combined, the former providing the variable population on which the latter operates.

The question is often asked whether it is not possible to inoculate plants against disease, but so far all researches in this direction have given negative results, and there is no evidence in any single case that one attack confers resistance to a second.

Finally, a word must be said about recent work on Virus diseases of plants, which shows that in certain cases a plant may be permeated thoroughly by a virus and serve as a focus of infection to surrounding plants and yet show no symptoms of the disease. Sometimes, as with certain hops and potato Virus Diseases, entire varieties may be "carriers" of the disease and so appear to be resistant. Such plants may remain quite symptomless or the disease may be manifested under altered environmental conditions. In Virus Diseases true resistance

PLANTS, DISEASE IN, RESISTANCE TO (*Continued*)—
is apparently very rare. (See Virus Diseases, and Virus Diseases of the Potato, under Potato.)

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W. B. B.

PLANTS, HARDENING OF—See Refrigeration; and Winter Hardiness and Drought Resistance.

PLANTS, POISONOUS—It is probably true that losses of livestock due to poisonous plants are much greater than is commonly supposed, since the cause of a number of deaths appears to remain unexplained. It need not, of course, be assumed that poisonous plants of a deadly kind occur in every field, or even on every farm, but there are, nevertheless, quite a number of plants varying in their toxic character scattered up and down the country. Some such plants are peculiar to grass land, some are more frequently found in hedgerows by ditches and on waste spots, while others are associated with water or wet meadows.

Certain points of considerable importance which need to be borne in mind are: (1) that the plants vary widely in relation to the parts which are poisonous—some being poisonous in all their parts, while in others the poisonous property is mainly in the fruit, the root, or the foliage; (2) that the intensity of the poisonous property may vary somewhat with the season; (3) the toxic principle in certain plants is cumulative in the animal—that is, poisonous symptoms are not visible until a considerable quantity of the plant has been consumed over a period; (4) the different classes of livestock vary considerably in their susceptibility to plant poisoning, while even individual animals of the same class also appear to differ in this respect; and (5) certain species lose their poisonous character when dried and converted into hay, whereas others are poisonous in both the dried and green state.

Whenever an animal or animals on the farm are discovered to be suddenly ill for no apparent reason, one may well be suspicious, par-

PLANTS, POISONOUS (*Continued*)—

ticularly when the stock are at grass, of some form of poisoning, either of a mineral or of a plant origin. The safest course in such circumstances—and this applies particularly where the stock are especially valuable—is to call in a veterinary surgeon to diagnose. Should he suspect poisoning the stock should be moved immediately to another field and a thorough examination of the suspected area be made at once so that steps may be taken to eradicate any poisonous species which may be found.

It is deserving of note that the circumstances of poisoning may be such that adjoining owners may be involved in legal proceedings where the stock of the one have been able to reach and consume poisonous plants growing on the land of the other. In this connection it is observed in a publication of the Ministry of Agriculture that "it has been held that where a yew tree grew through and over a fence and projected on to a meadow occupied by the plaintiff the owner of the tree was liable for the loss of a horse which was poisoned by eating the foliage of the tree."

Eradication—The method of eradication will depend largely upon the species of plant, and whether it occurs in the open grass, in the hedgerows, or in the many waterways associated with water meadows and similar situations. Treatment for the eradication of poisonous plants should, of course, be more determined than in the case of non-poisonous weeds, and the attack should be followed by frequent observation thereafter and any further treatment that may be necessary. The means of eradicating poisonous plants depend upon the same principles as apply in the case of ordinary weeds (see also Weeds); that is to say, annuals and biennials may be largely destroyed by sufficiently early cutting to prevent seeding and repeating the operation as may be necessary, whereas the perennials need much more continuous and drastic treatment if they are to be successfully overcome, the treatment, moreover, varying with the type of perennial concerned. In some cases considerable difficulty may be experienced in getting rid of poisonous hedge weeds such as bryony and woody nightshade (bitter sweet), since such plants grow readily and rapidly from extensive root systems which need to be systematically uprooted and destroyed, but are intimately associated with the hedge roots.

Poisonous Species—Among the many poisonous plants which are most likely to cause trouble in connection with farm livestock may be mentioned the following, the most dangerous species being starred:

* Lesser spearwort (*Ranunculus flammula* L.).
* Celery-leaved buttercup (*R. sceleratus* L.).
* Corn cockle (*Agrostemma Githago* L.).
* Laburnum (*Cytisus Laburnum* L.).
Cherry laurel (*Prunus Laurocerasus* L.).
Bryony (*Bryonia dioica* L.).
* Hemlock (*Conium maculatum* L.).
* Cowbane or water hemlock (*Cicuta virosa* L.).
* Water dropwort (*Œnanthe crocata* L.).
* Fool's parsley (*Æthusa cynapium* L.).

PLANTS, POISONOUS (*Continued*)—

* Ragwort (*Senecio Jacobæa* L.).
* Deadly nightshade or dwale (*Atropa Belladonna* L.).
* Bitter-sweet or woody nightshade (*Solanum Dulcamara* L.).
Black nightshade (*Solanum nigrum* L.).
* Foxglove (*Digitalis purpurea* L.).
* Dog's mercury (*Mercurialis perennis* L.).
Annual mercury (*Mercurialis annua* L.).
* Oaks (acorns) (*Quercus Robur* L., and *Q. sessiliflora* Salisb.).
* Yew (*Taxus baccata* L.).
* Meadow saffron (*Colchicum autumnale* L.).
Lords and ladies or cuckoo pint (*Arum maculatum* L.).
Darnel (*Lolium temulentum* L.).
Horsetails (*Equisetum* spp.).
Bracken (*Pteris aquilina* L.).

Apart from the above-named species a considerable number of others are harmful from time to time, even causing death of animals affected, while still others are suspect.

Poisoning through Feeding Stuffs—It should be mentioned here that animal poisoning has occurred very frequently through the use of a feeding stuff which in itself is poisonous, as in the case of " Java " beans and the so-called Indian peas, or to the inclusion in an otherwise harmless feeding stuff of the seeds of poisonous plants such as corn cockle, charlock, darnel. It should also be mentioned that serious results may follow the ingestion of ergot, a parasitic fungus which occurs on rye and other cereals and on many grasses.

(For fuller information on the subject of poisonous plants, the following works should be consulted: " Poisonous Plants on the Farm," *Ministry of Agriculture and Fisheries*, 58 pages and 51 illustrations, 1927, and " Plants Poisonous to Livestock," H. C. Long, *University Press, Cambridge*, 2nd ed., 1924. The latter work contains an extensive bibliography.)

H. C. L.

PLASH—To maintain hedges as adequate fences against stock, pruning alone is not sufficient. Pruned hedges all tend to become open at the bottom, and the gaps so formed have to be filled up by plashing—that is, by the laying of a strong, healthy stem in such a position that young twigs will shoot up from it and eventually close up the gap.

Plashing is done by selecting the strongest stem adjacent to the gap and pruning it to the length of the gap. An upward cut, near the ground, is then made on the opposite side to the direction the stem is to be plashed. The cut is made just sufficiently deep as to allow the stem to be bent into a horizontal position close to the ground. The plashed stem is then fixed down either by wattling or by securing it below some offshoot.

PLOUGHING—The characteristic action of the plough is its more or less complete inversion of the layer of soil in which it moves. There are a number of circumstances in which this effect is desired, and which therefore point to the use of the plough in preference to other implements for stirring the soil. Inversion of the soil is an important object where a layer of dead or living vegetable matter must be

PLOUGHING (*Continued*)—

covered; dead matter in the case of manure and stubbles or root tops, and living matter in that of clover sward or weeds. By the exclusion of light, green tissues are destroyed; and when dead vegetable residues are incorporated in the soil, they are attacked by soil organisms and converted into humus and later into available plant food. As the soil organisms are less active in the lower and less aerated layers of the soil, however, very deep ploughing, except in light porous soils, may delay bacterial action on the said vegetable residues; and burying the soil bacteria at levels unfavourable to their activities materially affects the productivity of the soil for a time.

The greater activity of soil organisms in the upper 4 to 6 ins. of soil is one reason why it is desirable periodically to plough down the top layer, so that it may have a period of comparative rest, and bring up a fresh layer to the level at which germ life is most numerous. The third reason for ploughing is that discussed in the article on tillage, viz., to re-mix the soil particles, by bringing to the top the fine and colloidal particles which have been washed down into the lower regions during the preceding period in which the soil has lain undisturbed.

The time, manner, depth, and repetition of ploughing should be considered in relation to the effects of the operation. On light, porous soils, in which vegetable decomposition is rapid and in which tilth is improved by keeping the fine soil fractions in the upper layers, it cannot be said that *early* autumn or winter ploughing is advantageous in the cultivation of root crops after corn. Such weeds as escape extraction in the autumn cultivations can be destroyed by occasional shallow stirring during the winter; and the ploughing proper—advisedly a deep inversion in this case—may be deferred until about February or March, so that the fine material brought up will not be washed down again before the crop is established. Deep ploughing is here advantageous because the layer "worn" by the bacterial activities of the previous season is deep and because the lower layers contain more fine material, which is desired for improving the texture of light soils.

If heavy soil is left unploughed during the winter, the clay particles become puddled owing to their constantly saturated condition, with the result that the difficulties of forming a tilth suitable for a spring-sown crop are greatly increased. Heavy land should, therefore, be ploughed early to facilitate percolation, and the work should be done in a manner calculated to further this object. The winter rains pass down into the subsoil most quickly when the furrow is rectangular and unbroken, as left by a long-breasted or common plough, in contrast with the work of the short-breasted or digger pattern. Early ploughing also exposes the undersoil to the weathering agents for a longer period and thereby increases the chances of mellowing by frost. Autumn ploughing has also economic advantages over later work: besides facilitating the preparation of a better seed-bed in spring, it enables cultivations and seeding to be carried out earlier. In this matter the method of ploughing makes a difference, the less broken

PLOUGHING (*Continued*)—

furrow being dry and ready to work a week or two before the broken furrow.

Under certain exceptional conditions even on heavy soil local practice favours a late winter ploughing rather than early inversion. This is the case where heavy rains commonly follow the break-up of a long period of frost, with the result that the frost mould is destroyed and the soil runs together and hardens.

Difference of opinion is met with in practice concerning the desirability of a spring ploughing in addition to the autumn deep furrow. If the first ploughing was carried out at the time and in the method appropriate to the circumstances, spring ploughing may be expected to do more harm than good.

The importance of deep ploughing is usually exaggerated. The impression that deep working increases the depth of rooting of crop plants is true only where the subsoil is impenetrable owing to the presence of a hard pan. On soils not underlain by hard pan or plastic clay, plant roots pass down far below the depth reached by tillage implements; and experiments show that the time and manner of ploughing is of more importance than its depth. Good farmers generally practise deep working in the autumn preparations for root crops. Without the liberal additions of organic matter and fertilizers which are also part of the practice of good farmers, it is doubtful whether the extra inch or two of depth in cultivation would be advantageous.

The implements used for ploughing are far too numerous and varied, and much expense and inconvenience is caused by want of standardization in such fittings as shares. Special patterns of plough are admittedly needed for such conditions as rocky soils, in which the bar-point form is economical of breakages, but many of the slight variations in the three main types—long breast, digger, and intermediate or general purpose ploughs—are unjustifiable.

The cost of ploughing by horse teams, working on the basis of an output of 1 acre per day, is about 14s. 9d. per acre for two-horse work, and 17s. for heavier work requiring three horses. On the other hand, where conditions permit of three horses drawing a double-furrow plough, the cost is only 9s. per acre. This figure emphasizes the importance of increased output per man as a means of reducing costs. It is the greater area ploughed per day per man, rather than cheaper power, that makes tractor ploughing so much less costly than team work. Tractor work at 2s. 4d. per hour for eight hours plus man at 7s., total 25s. 8d. per day, makes the cost per acre about 9s. 7d. This is for an output of 3 acres per day, and includes an allowance of 1s. per acre for use of implement. As is mentioned in the article, Horses versus Tractors, ploughing is the one operation in which tractors are definitely more economical than horses.

J. R. B.

PLUM—See Stone Fruits, under Fruit; for methods of preservation by refrigeration see Refrigeration.

PNEUMOGRAPH—An instrument consisting of a rubber bag containing air, connected in an air-tight manner with a tambour and tracing pen, which records variations of pressure on the bag.

POTATO—The potato is one of the major farm crops. It is grown very generally, but its cultivation as a commercial crop is restricted to a few districts.

The acreages of potatoes found in the different parts of Great Britain and Northern Ireland in 1925 ("The Agricultural Output of England and Wales, 1925"; *ditto*, Scotland, 1925; *ditto*, Northern Ireland, 1925) were as follows: (For purposes of comparison the relevant figures for 1930 are given also.)

	1925.	1930.
England Wales	493,000	422,600
Scotland	142,000	123,358
Northern Ireland	154,384	136,294

The largest acreage in any one county is grown in the Holland Division of Lincolnshire, where nearly one-third of the arable land is under potatoes every year. The next largest acreage is in the Lindsey Division of Lincolnshire, which is closely followed by Lancashire and the Isle of Ely; potatoes are also grown in considerable quantities in the West Riding of Yorkshire and in Kent. In 1929, fourteen counties in England accounted for an acreage of 363,981 out of a total of 496,224 acres (see Fig. 17).

In Scotland, potatoes are grown on a considerable scale in Ayrshire, in the Lothians, in Perthshire, and in Forfarshire. Potato growing in Scotland has developed chiefly along the east coast.

The potato is an important crop on most farms in Ireland. It is, however, more largely grown in the counties adjoining the sea, and more particularly in the west. Ireland produces almost as many potatoes as England and Wales, and has under one-tenth of the population of the latter countries. Although large quantities of the crop are used for human consumption and for stock feeding in Ireland, there is a large surplus available for export after both these demands are satisfied.

Certain districts are noted for the production of early potatoes: such are Cornwall, where, however, the acreage is small, Ayrshire, and the Holland Division of Lincolnshire, where the acreage is large. These early districts generally border on the coast, but beyond this fact it is difficult to account for the earliness of particular districts. For instance, early potatoes are easily produced along the northern coast of the Wash from Boston to Wainfleet, where lifting may commence before the middle of June, yet immediately across the Wash, along its southern boundary, early potatoes are not grown.

Soils—Potatoes will succeed on a variety of soils. The best yields are obtained on warp land, which contains about 50 per cent. of sand. Typical districts are in Yorkshire, in the area of the Humber, and the Holland Division of Lincolnshire. The Black or Fen Land in the Isle of Ely, and in Lancashire, contains a large amount of organic matter, and produces heavy crops, but usually of inferior quality.

POTATO (*Continued*)—

Potatoes also succeed well on medium sandstone soils—the " Red Sands " from Dunbar, and from Antrim in the North of Ireland, are well-known for their good quality.

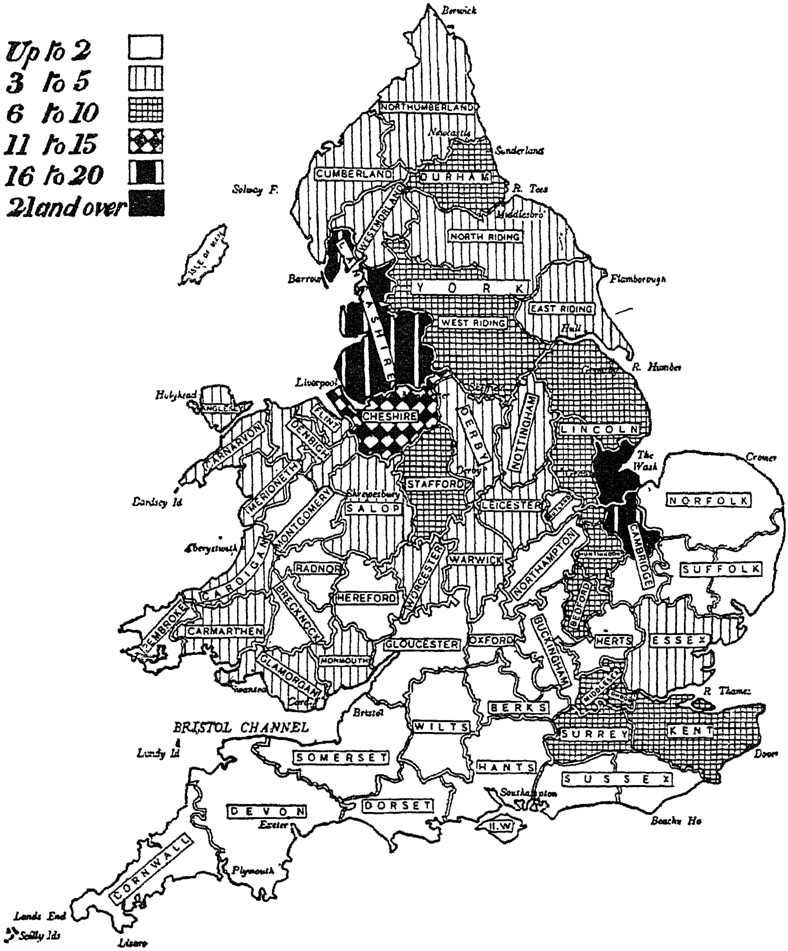

FIG. 17.—SHOWING THE NUMBER OF ACRES OF POTATOES PER 100 ACRES OF ARABLE LAND IN 1925.

(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationary Office.)

Soil has a considerable effect on the quality of the tuber. The best quality is obtained reliably on limestone soils, but the yields therefrom are usually not high. Sandstone and silt soils also produce good quality tubers, and perhaps the poorest quality is grown on Black Land. (See Warping.)

POTATO (*Continued*)—

The heaviest crops are obtained from soil which contains very little lime, and are, in fact, slightly acid. The application of lime even to Black Fen soil, which is distinctly acid, has been found to reduce yields.

Seed—The term " seed " is applied to the tubers that are used for planting, and does not refer to the seed of the fruit produced from the flower. There is a general movement of " seed " potatoes from north to south, not only in the British Isles, but on the Continent, and in some southerly districts it is only possible to obtain a satisfactory crop by introducing fresh seed from a more northerly area every year. In most districts in England a " change of seed," that is to say, a fresh importation of seed from a more northerly district, is necessary at least every two years. The reason for this change is now known to be due to the rapid infection and spread of Virus Diseases (*q.v.*), *i.e.*, Leaf Curl, Leaf Roll, Mosaic, etc., which takes place in the southerly districts. Aphis, or green fly, is recognized as the means by which the disease is spread. Plants attacked by Virus Disease produce only a light crop, generally of small tubers, and as the resultant plants from these tubers are even more unhealthy, a stock of potatoes may soon become useless.

Scotland, particularly the districts along the east coast, is the chief source of the supply of seed potatoes. The more northerly the district in which the seed is grown, the less virus it appears to contain. " Seed " growing has developed very considerably in Ross-shire, but good seed can be obtained from as far south as the Lothians.

There is a considerable demand in England for once-grown seed, *i.e.*, tubers grown once from Scotch seed, and Lincolnshire is noted for its seed of this description.

Good seed is also obtainable in Ireland, especially from the north-west part of the country, particularly Donegal, where the production and sale of " seed " has developed rapidly during the past few years. In Ireland it is frequently accepted that seed grown on " bog " land is the best.

It has been found in Lincolnshire that lifting " seed " in an immature condition, *i.e.*, before the parent plants have commenced to ripen, is not only a means of obtaining a heavier crop in the following year, but enables the grower to keep his stock at least a year longer without having to change it. The scientific reason for this result is probably that the early lifting is in advance of the aphis attack, which spreads Virus, or that the plants are lifted before the Virus infection has had time to penetrate from the leaves and stems to the tubers.

An attempt is being made to produce or select virus-free stocks of potatoes, for an account of which the reader is referred to the articles on Varieties of Potatoes, and Virus Diseases of the Potato, following.

The tubers used for seed purposes are generally those which are too small for disposal as ware. Ware potatoes are generally dressed over a 1¾ or 1⅝ in. riddle, and seed over a 1¼ in. riddle. This means that seed is therefore between 1¾ and 1¼ ins. in size. Scotch seed, however, is generally dressed over a 2-in. riddle, and is therefore larger.

Recent experiments at the Agricultural Institute, Kirton, have

POTATO (*Continued*)—

shown $1\frac{3}{4} \times 1\frac{1}{2}$ in. seed to be the best, followed by $2 \times 1\frac{3}{4}$ ins. In practice this would mean seed $2 \times 1\frac{1}{2}$ ins., this minimum being larger than that in general practice.

Seed for early potatoes is usually much larger than for maincrop, and is frequently sold as dressed through a $1\frac{1}{4}$-in. riddle with only the very large size picked off by hand.

Sprouting the Seed—The best crops, either of early or late varieties, are obtained from "sprouted" or "chitted" seed. Seed should be placed in chitting trays immediately after lifting. Chitting trays vary in size according to the district, but usually sixty trays, $2\frac{1}{2} \times 1\frac{1}{2}$ ft., are allotted per ton of tubers. Sometimes better results are obtained if eighty trays are allowed. In commercial practice it is not economic to place all the tubers with their "rose" or eye ends upwards, and, if properly treated, good sprouting can be secured without this elaboration.

The boxes or trays should not be left out in the fields for many days, as "blight" may attack the tubers. Immature seed usually shrivels badly, and the flesh may turn brown, but this is not detrimental to the potato for seed purposes.

The trays after filling may be placed in a barn, or better in a properly constructed glasshouse. Glass chitting houses should be provided with ample means of ventilation at the bottom, under the eaves, and at the ridge. They should also be provided with double doors, either at the side or at one end, to admit a cart.

The trays or boxes are made so that they can be built up one above the other, with space between each to admit light. They should be built up in tiers, each series of tiers being about 1 ft. 3 ins. from its neighbours. If the tiers are placed close together, less space is occupied, but the boxes have to be frequently rearranged to prevent the sprouts from becoming too long. Ordinary wood lathing is used to connect the tiers, to prevent their swaying over.

The sprouting houses may be provided with a hot-water heating system, which thereby secures better control of temperature. A high temperature is not necessary, and many houses are unheated except for a small stove, which may be used during frosty weather. In spring, full ventilation may often be necessary.

If sprouted in barns, which are generally dark, great care must be taken to prevent the sprouts from becoming too long, and frequent moving of the trays is necessary in spring.

Short, strong, thick sprouts, about 1 in. long, are the best; long, thin sprouts are easily knocked off either in planting or by the soil when it is ploughed over them.

Preparing the Soil—Potatoes succeed best after a leguminous crop, such as peas or clover. In Lincolnshire a one-year pure clover ley—a very little rye grass may be added—is put down for the purpose. The first crop of clover is made into hay, and the aftermath is allowed to grow until flowering time, when it is ploughed under as green manure. If farmyard manure is available, it is usually ploughed in with the

POTATO (*Continued*)—

clover aftermath. In Scotland and in some other districts, the yard manure is applied in the drills prior to planting, the tubers resting directly on the manure, but this method is usually not successful in a dry district.

Of recent years a practice has sprung up amongst maincrop potato growers in the south of the Holland Division of Lincolnshire of applying the manure in May and June to the growing crop, and working it in by means of the usual cultivations.

Deep cultivation is essential for the potato, and ploughing, therefore, should be deep, and the soil subsoiled where possible, an operation best done by a steam plough fitted with subsoiling tines.

If horses only are available, it is necessary to employ two teams. The first team does the ploughing, and the second follows with the subsoiler in the furrow made by the first plough. The fitting of a subsoiling tine to the ordinary plough is not satisfactory. Subsoiling should be done in the late summer or early autumn. If the land is ploughed in July, it is sometimes possible to sow cole or turnip seed on the ploughing, and to obtain a green crop which is ploughed in before winter. The success of this depends upon the soil and weather at the time of ploughing. In dry weather it may not be possible to obtain a tilth. Cross-ploughing in spring is not advisable.

Spring preparation for planting may commence as soon as the land is dry enough, and in early districts this may be in March. In districts subject to late spring frosts, too early planting of maincrop varieties is not advisable.

A thorough spring preparation is essential, and should be of sufficient depth to provide ample soil for ridging; at the same time, too fine a tilth is not advisable.

Ridges may be drawn with the ridging plough, or preferably with the three-row ridger, and in some localities a combined two-row ridger and manure distributor is used. The ridges should be spaced 22 to 24 ins. for early, 24 to 26 ins. for second early, and 26 to 28 ins. for maincrop varieties. Occasionally more than 28 ins. is allowed, but this is a waste of ground. In Ireland it is customary to use narrow ridges, maincrop varieties sometimes being grown in ridges 22½ to 24 ins. apart. Ridging should be done immediately in front of the planting. It is a mistake to draw the ridges too long in advance of planting, since, if the weather is dry, the potatoes, being planted on dry soil, make little headway until rains come.

Manuring—The potato responds to adequate manuring. It is necessary for the soil to be in good condition, and to contain a sufficiency of organic matter. The ploughing-in of a green crop, as mentioned above, helps to maintain the soil in high condition. On good land, such as is found in the best potato-growing areas, farmyard manure should be looked upon more as a soil conditioner than as a source of plant food, and heavy dressings are neither advisable nor economical. The farmyard manure must be supplemented by dressings of artificial manure, to which the potato gives generous response. A greater

POTATO (*Continued*)—

return is obtained from the artificial manure applied to the potato crop than from any other item in its production.

The quantity and kind of artificial manure used varies with the soil and the district. In some parts very heavy dressings are applied, and have been proved to be remunerative; in others the economic limit is reached more quickly.

On Black Land, it is frequently the custom to apply superphosphate only, but recent experiments on such soils in South Lincolnshire have shown that a complete manure gives better results.

A mixture of 6 parts superphosphate, 1½ parts sulphate of ammonia, and 1½ parts muriate of potash has given excellent results on Black Land. This mixture may be applied at the rate of 10 to 12 cwts. per acre.

It has also been the custom to apply considerable quantities of superphosphate, as well as ammonia and potash, to potatoes grown on other soils. The potato responds readily to ammonia and to potash, but recent work has shown that phosphate, in many districts, does not appear to be so necessary, and the quantity used formerly may be considerably reduced with advantage.

Compound manures sold for potatoes have until recently contained over 20 per cent. of phosphate, *i.e.*, about 13 cwts. of every ton of compound consisted of superphosphate. Many of these manures were too low in ammonia and very low in potash.

The following mixture has given excellent results in many parts of the country, and is based on the result of experimental work in Lincolnshire:

> 4 parts superphosphate, 2½ parts sulphate of ammonia, 2 parts sulphate of potash, and ½ part steamed bone flour, the latter being added as a drier.

If the compound is to be applied soon after mixing, the steamed bone flour may be omitted, as its inclusion is chiefly recommended to keep the mixture in an open condition.

This mixture may be applied at the rate of up to 15 cwts. per acre on good land. It may be added that the higher the condition of the land and its fertility, the larger the quantity of artificials that may be remuneratively applied.

Sulphate of potash gives a better-quality tuber than muriate of potash or potash salts. It is, however, more expensive, and the grower may not always obtain a higher price for better cooking quality potatoes. Kainit is not to be recommended for potatoes, except on very light land, and if used at all it should be applied to the land early in the previous winter.

Artificial manure is best applied in the drills just prior to planting. Manure distributors are more economical than hand-labour, but all are not efficient. Evenness of distribution is essential in the application of artificial manure.

Planting—Planting should be done from the chitting trays, two planters being employed to one tray. The tray should rest on two

POTATO (*Continued*)—

ridges, the planters walking in furrows 1 and 3. These two rows are planted on the outward journey, and rows 2 and 4 on the return journey. Care must be taken not to break off the sprouts when taking the tubers out of the boxes, and also not to damage them after being placed in the ground.

After planting, the tubers should be covered by splitting the ridges. This may be done with the ridging plough, or by the more modern and time-saving three-row coverer. Horses should be trained to walk on the ridges and not in the furrows, otherwise the tubers will be damaged.

Carting of the trays containing the sprouted tubers on to the field should not be done in front of the planters. If the carts are taken along the unplanted furrows, the bottom of the furrow is made hard and solid for the tubers.

The carts with the trays of seed potatoes should be taken along after the ridges have been split, and the trays carried to the required places. Proper organization is required to keep the splitting of the ridges and the carting of the tubers close up to the planting.

Treatment after Planting—About ten days or so after planting the field should be harrowed with chain harrows; this will destroy young weed seedlings on the ridges, and will also reduce the amount of soil covering the tubers. It is also necessary to cultivate between the ridges, in order to get a fine and sufficient tilth for earthing up.

A second harrowing should be given about a week or so after the first, but in the case of early varieties, care must be taken to see that the young shoots are not too far advanced.

Cultivation between the ridges is necessary after the plants have appeared, and should be repeated at least twice before earthing up. A spring-tine drag or cultivator, which will do three rows at once, is very useful for this purpose.

Earthing up should be carried out when the plants are about 1 ft. 6 ins. high, and before the tops have become large enough to be damaged during the operation. For this purpose the three-row ridger is a useful implement, doing the work equally well, if properly adjusted, and much quicker than the ridging plough.

Harvesting—Early and second early varieties are usually lifted when quite green, and sent off at once to market. Some second earlies, such as British Queen, keep well until Christmas, and may be lifted when mature and put into graves. Maincrop potatoes, if they are to be graved, should not be lifted until the skins have set.

In some districts lifting is done by hand, and where Brassica crops are grown between the rows of potatoes this method is compulsory.

Mechanical means of lifting are more economical and rapid than hand-labour, although such means can only be employed for removing the potatoes out of the soil, and placing them in a position for hand-gathering. No satisfactory machine that will lift the potatoes from the ground and put them either into bags or carts has yet been put on the market. Good results have, however, been obtained from a new Danish machine which does this.

POTATO (*Continued*)—

Spinners or diggers of various types may be used for lifting potatoes. A satisfactory spinner should leave the potatoes on the surface of the soil, so that the pickers have no difficulty in gathering them. The tubers should also be left in a narrow row. A serious fault of most spinners is the large amount of bruising done to the tubers; cutting of the tubers is visible at lifting time, but bruising without breaking the skin is difficult to detect until it becomes more obvious after the tubers have been graved.

Spinners are very suitable for lifting early and second early potatoes, which are to be marketed immediately, but many farmers prefer the old-fashioned potato plough when the potatoes are required for seed or are to be graved, on account of the smaller amount of damage sustained by the tubers.

Potato graves should not be too wide or too high, 6 or 7 ft. wide is sufficient, and small graves keep cooler than large graves. The potatoes should be heaped in a ridge formation and covered with straw. It is advisable not to cover with soil for a week or two unless it is late in the season, and there is danger of frost. A few spits of soil are of course necessary to keep the straw in position. About 4 ins. of soil should be sufficient for the first covering, but the top of the ridge must be left open as long as possible. Another layer of soil must be added later to keep out winter frosts.

Marketing—When once lifted early potatoes are sent to the market at once. They are usually dressed on an inch riddle to get rid of most of the soil, and are packed in barrels. Second earlies are also sent direct to market, and are generally packed in bags; these are usually dressed over a 1½ in. riddle, depending upon the season.

Maincrop potatoes are not lifted until ripe. They are generally put into "graves" or "clamps" and marketed throughout the winter. The minimum riddle used for maincrop is usually 1¾ ins., occasionally 1⅝ ins. may be used. Black Land maincrop potatoes are as a rule dressed over a 1½ in. riddle. At times the markets demand a larger sample, and a 2-in. riddle is then used.

There is generally a demand in most markets for a large sample, and for this reason Majestic, which grows to a large size, is a favourite variety.

Good cooking quality in potatoes does not always give the grower a correspondingly increased price. Opinions as to what constitutes a good potato appear to differ in the various markets, and whilst most people prefer dry, floury potatoes, many prefer the more waxy types. Potatoes are too frequently spoilt in the cooking. It is rarely that properly cooked potatoes are served in hotels or restaurants.

Insect pests—*Eelworm* has become a serious pest in several areas. Two kinds attack the potato—one, *Heterodera Schachtii*, damages the roots and restricts growth, with a resultant very small crop. In Lincolnshire, a dressing of 8 cwts. per acre of drained creosote salts has given good control. The salts should be applied to the land ten days before planting, and ploughed in about 4 ins. deep at once.

POTATO (*Continued*)—

The other eelworm, *Tylenchus dipsaci,* attacks the tuber, ultimately causing its complete decay. This eelworm does not affect the yield, but greatly reduces the market value of the crop. It spreads rapidly in the "grave." It is sometimes possible to grow a second early crop on infected land, and to market the crop before very serious damage has been done. Creosote salts have proved a useful control in this case also.

(For composition and feeding value of potato, dried potatoes, and potato flakes see Feeding Stuffs.) J. C. W.

POTATO, VARIETIES OF—Introduction—A potato variety has been defined as an individual in contradistinction to a race; inasmuch as every potato variety is ultimately derived from a new-born seedling plant which has multiplied vegetatively by means of its tubers so that it may cover thousands of acres in any season, so every plant wherever grown must be regarded as identical with the original seedling. Thus, we see that a variety is an extended individual or, as it is technically termed, a " clone," and not a race.

One variety may differ from another by as few characters as may go to distinguish one brother from another, or by as many as distinguish, let us say, an Australian aboriginal from a European.

Till recently we did in fact regard varieties as standing in just that sort of relation which brothers or cousins do to one another; they were all children of the same original parents; they were all members of the Linnean species *Solanum tuberosum.*

Such a view is still in the main true, the varieties common to Western Europe and North America are very closely related; indeed, they are all forms in which the chromosome number is $2n=48$, and in that sense they differ no more from one another than do the innumerable varieties of the garden *Antirrhinum.* Russian workers have recently shown that in South America, the native habitat of the potato, there are real races of cultivated potatoes which differ profoundly one from another, and that these races are characterized by different chromosome numbers—viz., $2n=48$, $2n=36$, $2n=24$ (Juzepczuk and Bukasov, *Proc. All Russian Conf. Genet.*, V. iii., p. 593, 1930). These distinct races have to some extent different geographical habitats. The same workers have shown that the European varieties were derived from South Chili, where the greatest diversity of the 48-chromosome group is to be found, a conclusion which had been reached previously on historical and other considerations.

It is noteworthy that when the potato reached Europe towards the end of the sixteenth century, it had been cultivated in Chile and Peru for hundreds and possibly thousands of years, and that there were, as the early Spanish Conquerors reported (Garcilaso de la Vega, 1609, ed. 1725, vol. i., p. 136), numerous varieties in use amongst the natives. We know of two introductions: the one recorded by Clusius ("Rariorum Plantarum Historia," 1601) as having come into his possession in 1588, and the other described by Gerard (*Herbal,* 1597). This latter, Gerard says, he received from Virginia; whether it came via Vir-

POTATO (*Continued*)—

ginia or not we do not know, but it is certain that it was neither a native of, nor a recent introduction into, that part of North America at the time he wrote.

The two introductions differed as regards tuber colour, shape, and flower colour, as well as in those minor haulm characters which go to differentiate the numerous varieties we possess today. One feature, however, was common to both, viz., their self-fertility, and from them have arisen by self-fertilization and crossing all the varieties which have been grown in Europe and America up till 1850. It so happened that Gerard's potato was white-tubered and round, Clusius's reddish-purple and long, thus bringing to the common pool all the genetic factors necessary for the well-nigh innumerable genetic combinations which are responsible for the diversity in both physiological and morphological characters by which we distinguish the cultivated varieties of today. The reader is referred to the article on genetics of the Potato for information on the breeding of varieties.

It has been said that a variety is an individual, and as such, a seedling which was raised in 1862 and christened "Champion" must be regarded as still with us in the countless thousands of Champion plants which may be growing to-day—unaltered in its inherent character, its descendants remain unaltered in their phenotypic expression. Such a statement is true for the majority of our varieties, but it has not a universal validity. A variety may mutate (see Genetics, and Cytology); a coloured variety may, in its subsequent vegetativecareer, suddenly in one (or more) of its plants "sport" a variant character. The mutation may affect the haulm or may be confined to the tuber: mutation in the latter, which is the organ of practical importance, may give us new forms. Thus, the purple Arran Victory may give rise to a splashed form or a white one. The russeted Field Marshal and Sefton Wonder are but mutations of Up-to-date and Great Scot, respectively. The new forms are for all practical purposes the same as the original, because the mutations seem never to affect the physiological characters such as maturity or susceptibility to disease, but logically they are equivalent to new varieties. (See Potato, Genetics of.)

The varieties which were in general use in England up till about 1850 were all derived from Gerard's potato, with, doubtless, an occasional crossing of blood from European sources, *i.e.*, Clusius's potato. It would serve no purpose to describe in detail the endless series which were thus grown, many of which we know to have been very mixed (J. Anderson, *Rept. Comm. Bd. Agric.*, 1795). At an early date varieties of different maturation periods were selected, and varieties bearing very coarse big tubers, such as the Ox Noble, were set aside for cattle feed. Of these old varieties but few remain. The best known and the oldest is the early variety Myatt's Ashleaf; this variety, which may be 150 years old, is still grown by many because of its earliness, yellow and consistent flesh, and good flavour. In the Orkneys and the more inaccessible parts of Scotland and Ireland some of the heavy cropping late varieties such as the Yam, Brown

POTATO (*Continued*)—

Rocks, Gaukis, and Grigor Cups—are still found in garden cultivation.

The stimulus to the production of new varieties prior to 1848, over and above man's native itch to produce "better varieties," was undoubtedly the deterioration or, as the term then was, the degeneration, of varieties. This degeneration, we now know, was the sequel of infection by Virus Disease (*q.v.*), and at various times during the 100 years prior to 1830 it threatened the very existence of the potato in England. In the Lancashire district in particular was this the case. The symposium of articles collected by the Manchester Agricultural Society in 1778 gives a vivid picture of the rapid downfall of varieties, the clamour for new ones, and the current views on the cause of the trouble.

The sudden and overwhelming attack of Blight (*Phytophthora infestans*) which first swept over the British Isles in the years 1845-47 introduced a new era in potato breeding. Goodrich, of Utica, U.S.A., introduced direct from Chile a native variety which he called Rough Purple Chili, and from it, by successive self-fertilizations, arose Garnet Chili, Early Rose, and Beauty of Hebron. The blood of these two later found its way into the English breeds. Wm. Stuart (*Proc. XVI. Ann. Meet. Pot. Assn. America,* 1929) has shown how practically every variety of any note to-day, either in the U.S.A. or Great Britain, has been derived in part from the Rough Purple Chili. In Britain it is to Paterson (1810-70) that we owe the real advance in potato production. Paterson's Victoria was possibly the first variety to combine good shape, smooth eyes, and heavy yield. (See W. Paterson, "On Propagating New Varieties of Potatoes," *Trans. High. and Agric. Soc. of Scotland,* vol. iii., 1870-71; and James Wilson, "Paterson of Dundee," *J.D.A.T.I.*, No. 1, 1918.) Other raisers, using Paterson's Victoria and the American Early Rose, gave us varieties like Magnum Bonum and Champion. (For further details see Salaman, "Potato Varieties.") These new outstanding varieties were of late maturity, and for many years they showed themselves more or less resistant to Blight. From 1870 till about 1910 variety production pursued the even tenor of its way, many excellent potatoes being put on the market, of which several are with us to-day (see Table V.). In this period the names of J. Clark, A. Findlay, Robert Fenn, and Messrs. Sutton and Son stand out. Confining our attention to those varieties still grown commercially, we owe to Findlay the introduction of the remarkable trio of first-class varieties: Up-to-date, British Queen, and Majestic; to J. Clark, Magnum Bonum, Epicure, Ninetyfold; to Messrs. Sutton and Sons the introduction of Clark's varieties, as well as May Queen and Abundance; and to Robert Fenn the International Kidney. (See Potato, Fungus and Bacterial Diseases of.)

Although Wart disease (*Synchitrium endobioticum*) had occurred spasmodically in England as early as 1890, it was not till 1907 that it began to cause alarm. Gough was the first to realize the existence of varieties immune to this disease, which appeared at one time to

POTATO (*Continued*)—

threaten the very existence of the potato. The Ministry of Agriculture, acting on Gough's initiative, and with the help of the late J. Snell, soon achieved a complete classification of existing varieties as regards their immunity or susceptibility. In the list of outstanding varieties still in use (p. 924), those which have been found to be immune are starred, not many of which were in existence prior to 1910. It will be seen how serious the position might have become had Wart disease spread at the speed it first threatened to do. Not one good early or second early was amongst the immune, and no high-yielding maincrop, while Up-to-date, the finest variety ever raised in any country, stood condemned. The threat thus shown to one of our most important food crops was but an invitation to breeders and seedsmen to repair the breach in our defences against disease. In the forefront of all potato raisers in this latest era is Donald McKelvie: he has given us immunes which fill many of the gaps. Thus, in Arran Crest we have an immune first-early—earlier and a heavier yielder than Epicure; in Arran Banner and Arran Victory, heavy cropping immune maincrops.

In the rush to get out immune earlies, raisers have departed from the accepted canons and have given us round and even deep-eyed tubers. In the other maturity classes, too, nearly all the new varieties are of a similar type. Lately a change has set in, and good-shaped, shallow-eyed ovals and kidneys are being introduced, but not one of these has completely established itself as yet, except Majestic.

So far, Wart-immune varieties have not ousted the leading susceptible stocks, nor does any immune variety fetch so high a price as King Edward.

Classification of Varieties—Many classifications have been constructed, and readers are referred to Salaman ("Potato Varieties") for a discussion of schemes, for none of which the writer can find a use. Grouping of varieties into maturity classes is desirable, and is followed in the list of varieties at the end of this article. Certain peculiarities and fashions, however, appertain to both maturity groups and geographical areas which, with the particular usage of certain varieties, deserve some comment.

Description of Varieties in Common Use—*First Earlies* should have colourless or almost colourless skins, be kidney-shaped, and have yellow close-textured flesh. Large croppers are not so desired as those which bulk their tubers early. **Epicure,** the most widely grown early, holds its own, though it is of an ugly round shape, deep eyed, white fleshed and of a poor flavour, because it bulks early, retains its vigour and, to a greater extent than any other variety, withstands frost. The recently introduced **Arran Crest** is a dangerous rival, and is making headway in Lancashire. As field potatoes, **Ninetyfold** and **May Queen**—the former in Lancashire and the latter in Cheshire—are, after Epicure, the most widely grown varieties. **Duke of York,** which has a smaller area as a field potato, is a favourite garden potato, and is much used for forcing; its deep-yellow-coloured flesh and its excellent flavour make it very suitable. All the above varieties are

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susceptible to Wart disease. **Di Vernon** is a true first early of distinctive appearance, very good shape, yellow flesh, and immune; its yield is often poor owing to its proneness to virus disease. It is used at present as a garden variety.

Second Earlies: The qualities demanded in the first earlies do not hold in their entirety for this section; here, good-sized, white- and floury-fleshed tubers with heavier crops are preferred. In this group the chief varieties are: **British Queen,** a rather clumsy kidney type, but a very hardy variety, and a heavy cropper which is much grown in the Isle of Ely; it is susceptible to Wart disease. **Eclipse,** a kidney, is grown as a field potato, especially in Yorkshire and Lincolnshire. It is of good quality, but very susceptible to Wart disease and to blight. **Sharpe's Express** is sometimes regarded as a First Early, but may with equal satisfaction be classed as a Second Early; it has a wide use in gardens, and conforms in all the respects mentioned above to the ideal type; as a field crop it is grown in the Isle of Ely and Cornwall; it also is susceptible. **Boston Kidney,** more commonly known as Dargill Early, is a beautiful-shaped white kidney, with yellowish flesh, and is grown in the Scillys from seed raised in Lincolnshire; it is immune to Wart disease. **Ally,** also immune, is a round-tubered variety with shallow eyes, which, notwithstanding its poor cooking quality, has grown in popularity of late, especially in Yorkshire. **Royal Kidney** is grown extensively in the Isle of Ely district for export seed purposes. It is susceptible to Wart disease, is of an excellent kidney shape, but tends to bear numerous rather small tubers, hence its value as an imported first early variety. **Great Scot:** this potato is in some respects the most outstanding English variety; it retains its health and vigour to a remarkable degree, and is immune to Wart disease. It has a white skin and white flesh which, on boiling, is of a medium floury texture and a pleasant taste. It is a heavy cropper, and does well on most soils. Its failings are its round shape and rather deep eyes.

Maincrop Varieties: This group contains the most widely grown potatoes, especially south of the Border. **King Edward,** notwithstanding its susceptibility to Wart disease, is the most popular variety; its excellent kidney shape, smooth (shallow) eyes, its ready response to heavy manuring on good deep soils, all commend it, whilst the red patches around the eyes give it a characteristic appearance which enables the housewife to identify the variety she asks for. This variety commands an enhanced price which, dictates of fashion apart, is justified by the fact that of all commercial potatoes it blackens less after cooking than any other, and thus is particularly suitable for high-class hotel work. **Majestic** is an immune variety which produces white, large-sized, kidney-shaped tubers of medium quality only; it is, however, very extensively grown in Lancashire and Yorkshire, and is popular with the fried chip trade. **Arran Chief** is a susceptible, white-skinned oval, with medium shallow eyes and of excellent quality; it is not so popular as heretofore, as it is very subject to Virus infection and Blight. **Up-to-date,** once so popular, is not much grown now

POTATO (*Continued*)—

as a field crop in England, but still commands a considerable acreage in Ireland. When healthy, there is no variety to compare with it in quantity and quality of crop, in size and shape of tuber, nor, incidentally, in the beauty of its bushy haulm crowned with a wealth of heliotrope bloom. **Arran Banner,** McKelvie's latest immune variety, is a very heavy cropper and of promising quality, but its shape—deep-eyed, round—is against it.

Late Varieties: **Kerr's Pink.** This variety is very widely grown in Scotland and Ireland and the north of England. It is immune to Wart disease and, because of its lateness, resistant to Blight; a very heavy cropper and of good quality, *i.e.*, floury when cooked; moreover, it is a variety which will do better than most others under poor conditions of manuring and soil. But against these good qualities is the fact that it is red-skinned, of an ugly flattish round shape with deepish eyes, and much addicted to secondary growth. **Golden Wonder** is a Wart-immune, late variety which, by reason of its excellent quality and flavour, commands a good price, and hence is still grown, although its yield is generally much lower than that of any of the maincrop or late varieties which have been mentioned. It is always more or less visibly infected with serious Mosaic disease; a strain lately introduced by J. Chisholm, of Banff, holds out distinct promise of better health and larger yield.

Varietal Resistance to Blight—Reference has already been made to the first great outbreaks of *Phytophthora infestans* in 1845-47. The devastation of the crops was paralleled by an economic collapse in those backward parts of the kingdom where the potato was the mainstay of life. In Ireland, the after effects of the Potato Blight and ensuing famine can be readily traced in the economic and political history of the country. The variety Champion, which was introduced into Ireland about 1876, and which grew so rapidly into popularity that it became almost the sole variety grown, won its success by the fact that it was more or less resistant to Blight, and thus became an object of great economic importance. To-day it is no longer resistant, but, on the contrary, highly susceptible. For a full account of this variety see W. Davidson, *Econ. Proc. Roy. Dublin Soc.*, p. 319, 1928. Other varieties, such as Magnum Bonum, have followed on the same trail and have been hailed as disease resisters, but because of their susceptibility are no longer cultivated. What is the explanation? Are there any true Blight resisters amongst our domestic potato varieties? it may be asked. The truth seems to be that, looked at from the point of view of true inherent resistance, there is none such in use in Great Britain to-day, though D. Reddick (*Phytopathology*, vol. xviii., p. 483, 1928) finds an exception in the Japanese variety Ekishiraza, which he states is definitely resistant. The English varieties which at one time or another have been regarded as resistant are all of them late varieties, and the later they are the greater their apparent resistance. Blight has the most deadly effect when a potato plant has just reached, and is passing, its maximum physiological activity; if the variety is a late

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one, the seasonal attack of Blight strikes it whilst it is still on the ascending part of the curve of its life's activity and fails to gain a lodgment. If now these quasi-late varieties become chronically Mosaic-infected, their maturity is thereby hastened by as much as fourteen days, and, in consequence, the seasonal Blight attacks them at that period of their life when they have passed the apex of their growth's activity—with the result that they fall, like earlier varieties, an easy prey.

The relatively Virus-free stocks of old late varieties which have been raised by Professor Paul Murphy and Mr. W. Davidson in Ireland, and by the writer in Cambridge, have won back their resistance to blight disease in a very remarkable manner. The problems of Blight resistance and Virus disease are thus intimately related.

Salaman (*J. Genetics*, vol. i., No. 1, 1910) discovered in 1909 that resistance to the attack of *Phytophthora infestans* could be inherited in a Mendelian manner, and that such a resistance existed in the wild hybrid species *S. edinense.*

Research of late years by Müller (*Zeit. f. Pflanzenzucht*, Bd. xiii., p. 143, 1928) has shown that there is in various wild tuber-bearing solanums a genetic resistance to blight; on the other hand, Müller fails to find any such inherent resistance in the domestic varieties. Work by the writer (unpublished) confirms the first part of Müller's statement, but not the latter in its entirety. (See article, Potato, Genetics of.)

If we are to combat Blight by the use of suitable varieties, it thus appears that the problem will not be solved until we have bred entirely new types genetically resistant to the attack of the fungus, and at the same time resistant to or tolerant of the more destructive Virus Diseases of the Mosaic group. Inasmuch as this involves crossing domestic with wild types in order to bring in the disease resistance from the wild, the task will be complicated by the fact that there will be more characters of the wild which will need elimination than adoption.

Varietal Resistance to Virus Disease—It has been pointed out already that varieties degenerate and pass out of cultivation by reason of their infection with Virus Disease. Not all varieties display the symptoms of the Virus Disease with which they may be infected; they may, indeed, appear absolutely healthy; thus, King Edward, of which there is possibly no Virus-free stock extant, all being infected with Paracrinkle (Salaman and Le Pelley, *Proc. Roy. Soc.*, B., vol. cvi., 1930), can, if not otherwise infected, assume the appearance of perfect health. Up-to-date appears always to be carrying in a latent state a virus which can give a deadly streak to certain other varieties; British Queen does the same; and the new variety Di Vernon is rarely free from a virus which is equally destructive to others. When one reviews the list of the varieties which carry or tolerate Virus infection best, one finds that it contains the names of those sorts which have both survived the longest, and are or have been the most popular. There is, however, one Virus Disease which is very rarely if ever latent, and that is Leaf Roll (*q.v.* under Virus Diseases of the Potato). This disease cripples

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the plant often in its first season of infection, and practically always in the subsequent one. The only variety which seems to show some degree of tolerance to Leaf Roll is Great Scot. An exception to the rule that the oldest varieties are the best carriers is Epicure. This variety readily succumbs to both Leaf Roll and to the Mosaic group of infections. Indeed, its intense susceptibility, leading to early death of the infected plant, is probably the key to the variety's survival, for such plants leave either no tubers or such poor and blind ones that they do not survive to pass their taint into the next year's crop.

The future of the potato would seem therefore to lie either with the propagation of carriers or in the production of Virus-free stocks. This vital problem remains yet to be settled. If "carriers" could be selected which are not subject to any infection other than that they themselves carry, the future would seem to lie with them.

In Scotland, Canada, and many foreign countries, a system of registration is in vogue by which crops destined for seed production are specially inspected for the presence of Virus Disease. This policy undoubtedly tends to raise the quality of the seed. It does not, however, as has been supposed, go very far to eliminate Virus Disease, with the important exception of Leaf Roll. Most of the latter would be discovered on inspection owing to its very low degree of latency. On the other hand, it does go a considerable way to maintain "carriers" free from such other Virus Disease combinations which it is beyond their power to carry.

At the Potato Virus Research Institute at Cambridge much work has been done both to investigate these diseases and secure stocks of our most grown varieties as far as possible free from Virus Disease. Much success has attended the work in its early stages, and the increase in yield of Virus-free stocks over normal commercial ones is in the neighbourhood of 25 per cent. The difficulty which has still to be overcome is, whilst propagating these on an economical scale, to retain their health. It is at present too early to speculate on the ultimate results of the work, but certain deductions may be safely drawn which have a bearing on the cultivation of the potato and to some extent on the disease of varieties; these may be put in the form of rules:

Rule 1. *Never plant two different varieties in the same field, or in close proximity to each other.* Certain varieties, however healthy they appear, are 100 per cent. infected with Virus Disease; such a variety is King Edward. Paracrinkle, the latent disease of King Edward, is conveyed by insects to neighbouring varieties; in particular is it highly destructive to Arran Chief and Arran Victory. Other varieties, such as Up-to-date and Kerr's Pink, are sources from which latent Virus Disease may spread to other varieties less tolerant. For different reasons, President may help to spread Leaf Roll.

Rule 2. *Clean cultivation is essential.* Not only is thorough and clean field cultivation of value in enhancing the yield, but it is a valuable aid in keeping the stocks free from Virus Disease. Groundkeepers from former potato crops are a fertile source of Virus infection. At least two years should elapse, and better still four, between the

POTATO (*Continued*)—

sowing of the same field with potatoes. The weed *S. nigrum* (black nightshade) is a carrier of the Mosaic group, and *S. dulcamera* (bitter sweet), common in the hedgerows, of some types of Virus Disease also.

Rule 3. *Maintain wide, clean headlands, and cut all baulks and hedgerows.* Hedgerows, grass, and baulks harbour insects some of which may spread Virus infection; but apart from this the jassids and capsids which congregate in such do serious physical damage to the haulm of the plants which happen to come within their range of action.

Varietal Yields—The yield of any variety at any time or place depends on three factors, which may be arranged in order of importance as follows:

1. *The Health of the tuber seed planted,* which may be considered under two heads:

   (*a*) Virus Disease. Is the seed free of Leaf Roll and the mosaic group of diseases, or, if not free of the latter, is it tolerant to such ? (See Potato, Virus Diseases of the.)

   (*b*) Fungoid and bacterial infection. As many of these complaints are visible, suitable precautions may be taken. (See Potato, Fungus and Bacterial Diseases of the.)

2. *The Environment, i.e.,* soil, culture, manure, etc. (See Potato Culture.)

3. *The Variety*—It is this yield-determining factor which interests us here. Other things being equal, the varietal factor is important. (See Potato, Genetics of.) To measure it, carefully planned statistical trials extending over several years and in several different environments are necessary. Such trials have been carried through by the National Institute of Agricultural Botany, and have resulted in the calibration of the yields of the chief varieties in each maturity class as compared with a standard variety of that class. Those varieties which are nearly equal are grouped together, but their position within such group is indicated by the order of the names. A significantly superior yield is one which differs from its competitor by three times the probable error of the trial.

Varietal Maturity—The maturity of the different varieties has been calculated by the National Institute of Agricultural Botany at the same time as the yields; here, again, environment and the preparation of seed sprouting, boxing, and the like, all influence the actual period of maturation. In these trials all the varieties have been treated alike. In Table IV. the significant differences in the statistical sense are given where possible; when it is not available, the order represents the approximate place of the variety.

Synonyms—It is only in recent years that the custom of selling the same variety under different names has been checked (see Salaman,

POTATO (*Continued*)—

"Synonym Reports," *J.N.I.A.B.*, vols i. and ii.) How great the evil was may be gathered from the fact that Up-to-date has over 200 synonyms, Abundance over 100, British Queen a similar number, and other varieties numbers which vary directly with their popularity. A systematic study of varieties has resulted in the elimination of a very large number of these synonyms, thus rectifying a condition that was detrimental to the best interests of potato growers. It is still, nevertheless, desirable for growers to make sure that a variety advertised as new is really so, and not an old one renamed. Reference to the publication "Varieties of Potatoes with their Synonyms" (Heffer, Cambridge), and to the annual reports of the National Institute of Agricultural Botany, will give all the information necessary on this point.

TABLE I.

ORDER OF MERIT OF YIELD OF FIRST EARLY VARIETIES.

Varieties.	*Order of Merit in regard to Yield.*	*Order of Merit in regard to Ware.*	*Are significantly superior to the following in the order given.*	*Ware as Percentage of Total Yield.*
Arran Crest	1	1	Epicure. Duke of York and Sharpe's Express. Irish Cobbler. Ninetyfold. May Queen. Snowdrop. Di Vernon. Immune Ashleaf.	95·0
Epicure	2	3	Duke of York and Sharpe's Express. Irish Cobbler. Ninetyfold. May Queen. Snowdrop. Di Vernon. Immune Ashleaf.	90·6
Duke of York ..	3	6	Irish Cobbler. Ninetyfold. May Queen. Snowdrop. Di Vernon. Immune Ashleaf.	85·3
Sharpe's Express ..	4	7		84·1
Irish Cobbler ..	5	2	Ninetyfold. May Queen. Snowdrop. Di Vernon. Immune Ashleaf.	91·4
Ninetyfold	6	8	May Queen. Snowdrop. Di Vernon. Immune Ashleaf.	82·1
May Queen	7	4	Snowdrop. Di Vernon. Immune Ashleaf.	87·7
Snowdrop	8	9	Di Vernon. Immune Ashleaf.	79·2
Di Vernon	9	5	Immune Ashleaf.	85·6
Immune Ashleaf ..	10	10	None.	76·2

POTATO (*Continued*)—

TABLE II.

ORDER OF MERIT OF YIELD OF SECOND EARLY VARIETIES.

Varieties.	*Order of Merit in regard to Yield.*	*Are significantly superior to the following in the order given.*
King George ..	1	Great Scot. Arran Comrade. Boston Kidney.
Great Scot	2	Arran Comrade. Boston Kidney.
Arran Comrade ..	3	Boston Kidney.
Boston Kidney ..	4	None.

TABLE III.

ORDER OF MERIT OF YIELD OF MAINCROP AND LATE VARIETIES.

Varieties.	*Order of Merit as regards Total Yield.*	*Order of Merit as regards Percentage of Ware.*	*Are significantly superior to the following in the order given.*	*Total Yield as Percentage of Kerr's Pink =100.*	*Ware as Percentage of Total Yield.*
Arran Banner ..	1	1	Ally. Tinwald Perfection. Arran Chief. King Edward. Bishop. Golden Wonder.	101·0	91·0
Kerr's Pink ..	2	11		100·0	76·4
Majestic	3	2		96·0	89·5
Incomer	4	4		96·0	88·0
Field Marshal ..	5	6	Arran Chief. King Edward. Bishop. Golden Wonder.	95·0	80·0
Up-to-date ..	6	7			77·7
Arran Consul ..	7	3	Tinwald Perfection. Arran Chief. Bishop. Golden Wonder.	89·2	88·2
Roderick Dhu ..	8	10		87·9	76·5
Ally	9	5		78·6	81·8
*Tinwald Perfection	10	12	Bishop. Golden Wonder.	79·5	73·8
Arran Chief ..	11	8	Bishop. Golden Wonder.	77·3	77·1
King Edward ..	12	9		75·3	76·6
Bishop	13	13	Golden Wonder.	70·0	71·0
Golden Wonder ..	14	14		58·0	50·0

* There are reasons for keeping this variety below that of Ally, although its average yield is a little better.

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TABLE IV.

First Early Varieties.

Variety.	*Significantly earlier than—*
Di Vernon	Ninetyfold. Epicure. Irish Cobbler. Snowdrop. Sharpe's Express and May Queen.
Ninetyfold	Epicure. Irish Cobbler. Snowdrop. Sharpe's Express and May Queen.
Epicure	Irish Cobbler. Snowdrop. Sharpe's Express and May Queen.
*Irish Cobbler	Snowdrop, Sharpe's Express and May Queen.
Snowdrop	Sharpe's Express and May Queen.
Sharpe's Express May Queen	None.

Second Early Varieties.

Variety.	*Significantly earlier than—*
Arran Comrade	Boston Kidney. Great Scot. King George.
Boston Kidney (Dargill Early)	Great Scot. King George.
King George	None.

Maincrop and Late Varieties.†

Variety.	*Significantly earlier than—*
Ally	Tinwald Perfection. Bishop. Majestic. Golden Wonder. Arran Consul. Arran Chief. Up-to-date. Field Marshal. Kerr's Pink.
Tinwald Perfection	Arran Consul. Arran Chief. Field Marshal. Kerr's Pink.
King Edward	Arran Consul. Arran Chief. Up-to-date. Field Marshal. Kerr's Pink.
Bishop	Kerr's Pink.
Majestic	Arran Consul. Up-to-date. Field Marshal. Kerr's Pink.
Golden Wonder	Kerr's Pink.
Up-to-date	Kerr's Pink.
Arran Chief	Kerr's Pink.
Field Marshal	Kerr's Pink.
Kerr's Pink	None.

* This variety, known in America as Irish Cobbler, is in England often referred to as America.

† In many cases direct comparisons were not made between all the varieties, and only those actually compared are given in the second column. The list of varieties, however, represents the nearest approximate estimate of their relative maturity.

The list on p. 924 contains the names, together with certain useful particulars, of those varieties which are in common use to-day. There are, however, many others, some of considerable value, both in the garden and field, which are worthy of consideration. The reader is referred to the appropriate works mentioned in the bibliography for such information in regard to Great Britain, Germany, and the U.S.A. In respect to the varieties in use in France, see Salaman, " Potato Varieties," p. 201.

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TABLE V.

A LIST OF VARIETIES IN COMMON USE.

Name.	*Skin Colour.*	*Shape.*	*Eyes.*	*Year of Intro-duction.*
First earlies:				
*Arran Crest	White	Round	Medium	1928
Duke of York	White	Kidney	Shallow	1891
Epicure	White with purple tinge	Round	Deep	1897
May Queen	White	Kidney	Shallow	1900
Ninetyfold	White	Kidney	Shallow	1897
*Di Vernon	White, purple splash	Kidney	Shallow	1919
Second earlies:				
*Ally	White	Round	Shallow	1915
*Boston Kidney (Dargill Early)	White	Kidney	Shallow	*c.* 1900
British Queen	White	Blunt kidney	Shallow	1894
*Great Scot	White	Round	Medium deep	1909
Royal Kidney	White	Kidney	Shallow	1899
Maincrops:				
Arran Chief	White	Round-oval	Medium shallow	1911
*Arran Victory	Purple	Round-oval	Medium deep	1918
*Arran Banner	White	Round	Deep	1927
King Edward	White with red patches	Kidney	Shallow	1902
*Majestic	White	Kidney	Shallow	1911
Up-to-date	White	Kidney	Shallow	1894
Lates:				
Champion	White	Round	Deep	*c.* 1876
*Golden Wonder	Russeted white	Cylindrical	Shallow	1906
*Kerr's Pink	Red	Round	Medium deep	1917

* Indicates that these varieties are resistant to wart disease.

REFERENCES.—Board of Agriculture for Scotland, "The Maintenance of Pure and Vigorous Stocks of Varieties of the Potato," Edinburgh, 1927; W. Davidson, "Potato Growing for Seed Purposes," *J. of Dept. of Land and Agric.*, Dublin, vol. xxiv., 1924; T. McIntosh, "The Potato," Oliver and Boyd, Edinburgh, 1927; W. H. Parker, "Reports of Yield and Maturity Trials," *J.N.I.A.B.*, vols. i. and ii., 1922-30; W. E. Safford, "The Potato of Romance and Reality," *J. Heredity*, vol. xvi., 1925; R. N. Salaman, "Potato Varieties," University Press, Cambridge, 1926; K. Snell, "Kartoffel Sorten," Paul Parey, Berlin, 1929; W. Stuart, "The Potato," Lippincott, Philadelphia, 1923.

R. N. S.

POTATO (*Continued*)—

POTATO, GENETICS OF—Introduction—The potato has been studied by relatively few workers in genetics; in the early days its neglect was accidental, in the latter intentional. At first sight the potato appears a peculiarly suitable plant for genetic analyses, thanks to the ease with which any individual can be perpetuated by tuber and subjected to further experiment; in practice, it is one of the worst. The susceptibility of the domestic breeds to virus disease, and the facility with which the majority of young seedlings founder, make it impossible to carry on prolonged in-breeding, hence the analyses of many interesting problems, particularly such physiological attributes as the inheritance of yield, and maturity, remain in their present sketchy condition. In the field of chimæra study it is otherwise; and here the potato has proved itself an ideal subject.

Cytology and Polyploid Structure—It has been shown by V. Rybin (*Bull. Appl. Bot.*, Leningrad, vol. xx., p. 655, 1929) and H. B. Smith (*Genetics*, vol. xii., p. 84, 1927) and others that the wild tuber-bearing *Solanums* fall into groups whose chromosome numbers are $2n=72$, $2n=48$, $2n=36$, $2n=24$. (See Cytology.) These facts tend to confirm the view of Jørgensen (*J. Genetics*, vol. xix., p. 133, 1928) in regard to *Solanums* in general, and of Smith (*loc. cit.*) in regard to potatoes in particular, that the potato has been derived by a dual process of polyploidy and hybridization in a family where $n=12$ is the basic chromosome outfit. This view is shared by the writer. If such is the case, are the groups of twelve chromosomes in the domestic varieties strictly homologous? That they are not very unlike is evidenced by the absence of sterility on crossing. On the other hand, the wild types, so far as they have been tested, are generally sterile when crossed with the domestic potato, but this may well be due to the fact that the species employed have not always had the same gross number of chromosomes—viz., $2n=48$ type—as the domestic parent. The same consideration applies to the sterility observed between species. The successful mating of *S. utile* × domestic (see Salaman, *J. Genetics*, vol. xx., p. 311, 1929) resulted in F_2, F_3, and F_4 families, in the majority of which the *S. utile* character reappeared *in toto*. Mary Adams (*Verhandl. V. Internat. Kong. Vererb.*, Berlin, vol. ii., p. 1230, 1928) examined the material cytologically, and showed that *S. utile*, whose chromosome number was $2n=72$, in mating with the domestic potato $2n=48$, produced an F_1 with $2n=60$. In subsequent mitoses, however, whilst twenty-four domestic chromosomes united with twenty-four of *S. utile*, twelve of the latter remained unpaired and divided irregularly as between the two gametes. As pure *S. utile* families reappeared very generally in the subsequent generation, it appears that the *S. utile* set of twelve chromosomes has a greater affinity for a set of similar origin than it has for one of the domestic groups. Moreover, the more of these unpaired *S. utile* chromosomes there were in the gamete, the more *S. utile*-like the resulting plant. If none was present, the resulting plant was more nearly but never quite like the domestic parent. It seems therefore that the two domestic chromosome groups found in

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S. utile two partners sufficiently akin, leaving a third group of twelve who were less closely allied and carried the characters peculiar to *S. utile*. This species, which must be regarded as a hexaploid, is, however, completely self-fertile.

Rybin (*loc. cit.*) has shown that the tendency to polyploidy is still active in the somatic potato; whole areas of tissue in the roots have been found to be octoploid, *i.e.*, $4n = 96$.

Stow (*Jap. J. Bot.*, vol. iii., p. 217, 1927) also finds that the diploid number of chromosomes in the domestic potato is $2n = 48$, but that mitosis may be very irregular, and that irregularity is induced by high temperature and the presence of mosaic disease. This irregularity may well be due to the fact that the chromosomes of the potato are arranged in a tetraploid and not a simple diploid manner.

Most workers with the domestic potato must have been puzzled by the occurrence of unexpected characters in their genetic cultures, such as the occurrence of an occasional coloured flower in a progeny of white, selfed plants, or the rare occurrence of a black-tubered seedling from a beetroot-red-tubered parent, the reverse being the normal. It is possible that such cases are due to the tetraploid structure of the potato, which allows of a change in one gene whilst the three homologues are unchanged. Bukasov and his co-workers consider that primitive man grew several tuber-bearing solanums, and that our *Solanum tuberosum* must be regarded as a collective species. This would allow of genetic differences between the chromosome groups over and above that arising from subsequent mutation.

Inheritance of Morphological Characters—It is proposed to treat of the various characters in sequence from the inflorescence to the tuber. East was the first to work on Mendelian lines with the potato. His work in this direction was not pursued, but his observations (E. East, *Amer. Naturalist*, vol. xliv., 1910) have been in general confirmed by others.

Flower Colour—The range of anthocyanin pigmentation is purple, red and white. In all domestic potatoes the pigment is found in the upper layers of the corolla; in some wild species it is in the under, in others in both layers.

A simple monohybrid scheme of inheritance as regards the deposition in upper or lower layer of the corolla explains the phenomenon in regard to *S. edinense*, lower layer deposition being dominant (Salaman, *J. Genetics*, vol. i., p. 7, 1911).

The simplest genetic scheme explaining the presence of colour is the assumption by the same author (*loc. cit.*) of three factors, P, R, and D; D determines the existence of colour, R converts to red, and P and R together to purple. In such a scheme RD is red or heliotrope, and there will be several types of white, viz., R*d*, P*d*, DD, D*d*, and *dd*. It is clear that an R white crossed by a D white should give rise to coloured flowers, and such are indeed found. Two types of white can readily be distinguished: the one has a tinge of blue-purple developed on either side of the central green ligula of the corolla on the *under* surface; this

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character is linked with large, dark-yellow anthers containing abundant fertile pollen, and large corollas. The second type of flower is generally small, the corolla has often a yellowish tinge to it, and the anthers are generally small, pale, and not uncommonly deformed. The genetic formula of the first type has not been determined definitely, but it appears to be either R*d* or PR*d*. It is possible that modification of the above scheme may prove necessary (Black, *J. Genetics*, vol. xxii., p. 251, 1930), but so far no alternative scheme has been put forward.

Abundant v. *Sparse Flowering*—Heribert Nilsson (W. Weibull's *Arsbok*, vol. viii., p. 4, 1913) found that the F_1 between these two conditions was intermediate. Flowering, however, quite apart from varietal factors, is so deeply influenced by climatic conditions that it is difficult to differentiate such genetic influences as may exist. According to Stout (*U.S.A. Dept. Agric. Bull.* 1195, 1924), failure to flower is due to a premature separation of the flower bud at the corky ring on the pedicel. Successful pollination leads to a strengthening of this structure. The writer has found that inbreeding increases the tendency to flower, so that in F_4 and F_5 families nearly 100 per cent. of the individuals composing them flowered.

Pollen Sterility—The occurrence of anthers suffering from varying degrees of deformity associated either with absence of, or aborted, infertile pollen, is a common feature in the domestic varieties. The abnormal condition is dominant to the normal anthers and fertile pollen (R. N. Salaman, *J. Linn. Soc. Bot.*, vol. xxix., p. 301, 1910). In Edzell Blue, Salaman and Lesley (*J. Agric. Sci.*, vol. xii., p. 33, 1922) showed that the gene for sterility might be present in some of the female gametes and absent in others, whilst all the male gametes carried the gene for fertility.

Müller (*Angew. Bot.*, Bd. xii., p. 299, 1930) suggests that the abortion of anthers and sterility of pollen are results of the tetraploid structure of the potato and its consequent irregular mitoses. Against this, however, is the fact that sterility with aborted pollen is very common, and is not linked with abnormal segregation of other characters.

Berry or Fruit—In all domestic potatoes the fruit is round; very rare exceptions have been recorded where the distal end is pointed. In many wild, tuber-bearing *Solanums* the berry is long. Long berry is dominant, and the F_1 is cordate: the character is monohybrid (Salaman, *J. Roy. Hort. Soc.*, vol. xxxviii., p. 34, 1912).

Type of Inflorescence—In the potato, as well as in the wild tuber-bearing species, the inflorescence is borne on a primary axis which divides usually into two secondary axes, each of which forms a scaphoid cyme. There is, however, a compound type, as in Katie Glover, where the two axes divide again into a third, fourth, and even a fifth series, resulting in an almost cauliflower-like type of growth in which the individual flowers are small and often aborted (Salaman and J. W. Lesley, *J. Agric. Sci.*, vol. xii., p. 33, 1922). Where Edgecote Purple was used as a parent, it was found that the abnormal type appeared in subsequent generations, this character being presumably recessive to the normal. In tomatoes (M. Crane, *J. Genetics*, vol. v., p. 1, 1915)

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a like condition is met with, which behaves as a recessive monohybrid character.

Stem Colour—Anthocyanin pigment varying from purple to red is common in the stems of various varieties, and always present when the tuber is coloured; it may even be strongly developed when the tuber is white, as in Sharpe's Victor; in such cases the sprouts are bluish-purple. Intensification of colour at the axils of the stem or pedicels of the leaves is almost invariably correlated with coloured tuber eyes (Salaman, "Potato Varieties," 1926, University Press, Cambridge).

Salaman (*loc. cit.*, 1911) has shown that degree of colour in the stem is controlled by genetic factors, for a selfed family may be readily graded into 1 strongly coloured, 2 medium, 1 weak. K. Müller (*Ber. Deut. Bot. Ges.*, vol. xli., p. 60, 1923) explains the ratios of coloured stems to colourless, in which class he includes those with but a very small quantity of colour, by requisitioning three colour factors and an inhibitor. The writer is entirely in agreement with the desirability of postulating an inhibitor of colour; for such there is evidence in regard to tuber colour also. How far Müller's three factors coincide with the P, R, D of Salaman, which explain colouration in the tuber, is uncertain.

M. Sirks (*Genetica*, vol. xi., p. 293, 1929) distinguished between stem colour in the young seedling plant and that developed later. He ascribes distinct factors for this early pigmentation: B, a blue-producing gene which, when heterozygous, has no effect on the stems, but produces a blue colour in the axil; a similar factor, C, behaves in an analogous manner to B in the young plant, and produces a red instead of a blue colouration. Over and above these factors Sirks retains the P, R, and D factors of Salaman which are epistatic to B and C, so that RB causes a red and not a blue-purple stem. In all manifestations of colour in stem or tuber the D factor is requisitioned. Sirks' interesting and ingenious explanation of stem colour needs confirmation.

Habit of Growth—Potato plants may have an erect habit, as in Golden Wonder and Templar; a spreading one, as in Flourball and Majestic; or be prostrate. This last condition is met with very rarely; the early variety Harbinger presents the nearest approach to the true "prostrate" of the experimental plot. In the latter the plant creeps along the ground, and only the tips of the stems turn up vertically. In judging habit it must be remembered that chronic Virus Disease will often cause a pseudo-prostrate habit which may be the only symptom of the disease; such is not uncommon in Great Scot.

Salaman and Lesley (*J. Genetics*, vol. x., p. 21, 1920) showed that the true prostrate was a triple recessive, and was characterized by a well-defined condition of the stem, viz., the absence of the interfascicular xylem, leaving the three main bundles free and producing a curious rubber-tube-like consistence. The wings of such stems are absent or poorly developed.

The bushy type, which is dominant to the prostrate, is recessive to the upright, but its genetic relations have not been fully worked out.

Leaf Abnormalities—These are of two kinds: one, met with in

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seedlings, is often due to some physiological inhibition of the normal ontogeny, for if such aberrant seedlings be grafted onto a normal potato plant, the deformed scion will frequently recover and its leaves grow in a normal manner (H. Braun, *Arb. a. d. Biolog. Reichlt.*, Bd. xv., p. 671, 1928); the second class of aberrant leaf occurs in established varieties from time to time, and owes its existence to an anatomical disturbance of a chimærical nature.

Leaf Characters—These, such as shape, size, and spacing of the leaflets, development of the folioles, the erect or pendant condition of the leaf, all of which help so much in distinguishing one variety from another, have only been studied in crosses between a domestic variety and a wild species, *S. utile* (R. N. Salaman, *J. Genetics*, vol. xx., p. 311, 1929). Whether the findings have a validity for inter-varietal crosses is uncertain, though highly probable.

Apical Process of Leaflet—The fine-pointed terminal process always present in domestic varieties is scarcely developed or absent in *S. utile*. The presence of an apical process, such as is seen in the domestic varieties, is dominant and never lost in subsequent generations, unless all the other domestic leaf characters are too.

Blunt v. *Sharp Distal End of Leaflet*—This character is quite distinct from that of the apical process, and appears to be a monohybrid one in which "sharp" is dominant.

Large v. *Small Terminal Leaflet*—By "small" is meant a terminal leaflet whose area is not more than one and a half times that of the first lateral leaflet. In these crosses, small was a very definite dominant, and behaved as a monohybrid character.

Wide v. *Narrow Spacing*—This refers to the position on the main petiole of the leaf of the various secondary petiolules bearing the leaflets. "Narrow" has been taken as meaning that the space between the insertion of the first and second leaflets is less than one-half the entire length of the first lateral leaflet and its petiolules if any. This character is evidently a good one, and segregation was remarkably clean for a character so clearly quantitative in nature. "Narrow" is dominant and is monohybrid.

Stalked v. *Sessile Leaflet*—These alternative conditions are met with in the domestic series; the sessile condition is also found in *S. utile*. The stalked condition is dominant and monohybrid.

Angle of Insertion—The leaflets in the domestic potatoes are inserted on the main petiole at an angle of about 60°. In *S. utile* the angle is from 80° to 90°. The small angle of insertion behaves in these crosses just like the apical process: it is never absent except the entire group of domestic leaf characters be absent also.

Merging of Leaflet—By this is meant the gradual passage of the lamina of the leaflet into the petiole. It may affect terminal and lateral leaflets, and produce extraordinarily misshapen leaves. In some families there appeared good reason to regard it as due to one or more genetic recessive factors, but it has so much the appearance of the deformities described by Asseyeva, and explained by her as chimæras,

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that it would be unsafe to regard this tendency to deformity, which was brought in by the wild *S. utile*, as hereditary in the Mendelian sense, without further research.

Presence or Absence of Folioles—Folioles, *i.e.*, secondary leaflets, occur between the main lateral ones. The small and very sparse folioles found in *S. utile* and many wild species are readily recognized by the expert; for the sake of clearness it is here defined as a leaflet one-fifteenth the area of the first lateral leaflet. Related to "small" and possibly closely linked is the character "few" *versus* "many" folioles; similarly, "large" folioles are frequently linked with "many" folioles. The small and few foliole condition is a dominant character, and the segregation on a monohybrid basis is definite. "Small" and "few" folioles is the only character of the leaf derived from *S. utile* which is dominant.

Several of the pedigrees from which the genetic behaviour of these leaf characters have been deduced do contain exceptional plants: the occurrence of such plants is to be ascribed to the irregular mitoses already referred to.

Tuber Characters: *The Sprout*—The colour of the sprouts is commonly regarded as a valuable varietal characteristic. It develops in a moderate light, and is best observed when the sprout is about ¾ in. long. Sprouts are described as being blue, red, or colourless. The latter class is strictly non-existent; some small islets of coloured cells can always be found, but disregarding these and counting such as colourless, Müller (*loc. cit.*, 1920) shows good cause for the existence of three pairs of epistatic factors, each of which can produce some colour. It is of interest that neither he nor the writer finds any evidence of colour inhibitors in the sprout.

Tuber Colour—Most of the genetic work on the potato has been devoted to the colour of the tuber. We must, however, distinguish between the genetic colour pattern, *i.e.*, splashed tubers, coloured eyes, etc., and chimæras which may be phenotypically identical with them. In general, the latter, when selfed, give rise to colourless or self-coloured seedlings only (Salaman, *J. Genetics*, vol. xv., p. 267, 1925; Asseyeva, *J. Genetics*, vol. xix., p. 1, 1927); whilst the former when selfed produce either all splashed or splashed and colourless in a 3 : 1 ratio (Salaman, *Proc. IX. Inter. Hort. Congr. Roy. Hort. Soc.*, 1930).

An interesting fact first observed by T. McIntosh ("The Potato," Oliver and Boyd, Edinburgh, 1927) is that anthocyanin colour is developed in one of two positions: either (*a*) in the periderm and the upper cortical layer of the tuber, or (*b*) in the cortical layer only. In nearly every case parti-coloured, *i.e.*, splashed, tubers have coloured periderms, whilst in self-coloured tubers the periderm is colourless.

Krantz (*Proc. 13th Pot. Assoc. Amer.*, 1926) can find no difference in the scheme of colour inheritance between the two above classes. McIntosh's observation is probably of importance in relation to the study of chimæras.

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The scheme first put forward (Salaman, *loc. cit.*, 1911) for the existence of a factor D controlling the appearance of any colour at all; R, a factor which in the presence of D gives a red colour to the skin; and a further factor, P, which with R and D causes a purple coat, in the main holds good. At the same time the existence of a colour inhibitor or, what is the same thing, a dominant white was shown to occur in *S. etuberosum* (*S. edinense*). A difficulty which all workers have felt is how to explain and more particularly how to "score" those seedlings which bear tinted, red, or purple tubers. The tint may vary from an almost imperceptible flush of colour to one which is hardly to be distinguished from a self-coloured type. Black (*J. Genetics*, vol. xxii., 1930) invokes a factor H which inhibits D, but only incompletely where R or P is homozygous, thus producing a tinged colouration. As it is assumed to have less inhibitory effect when R or P is heterozygous, its action seems an anomalous one. He makes a further innovation, however, by assuming that whilst the combination of factors R and D causes red, that of P and D alone causes purple, whilst P, R, and D together produce a reddish-purple skin. The evidence for PD producing purple skins is insufficient, and if it prove correct would be an exception to the inheritance of purple anthocyanin colour in general.

Sirks (*loc. cit.*) accepts Salaman's scheme of colour factors P, R and D, and adds a further factor, S, which controls anthocyanin formation in the tuber only; on this scheme a red skin must contain R, D, and S; a purple need contain P, D, and S, and not necessarily the factor R. This hypothesis fits the facts rather better than the older one for self-coloured tuber colour.

Sirks further holds that RS*d* produces coloured eyes on a white skin, whilst "R, S, and D" produces colouration of the entire skin. This view does not seem quite satisfactory. Salaman ("Potato Varieties," 1926, and *loc. cit.*, 1930) has shown that pattern, *i.e.*, splash and eye colour, seems controlled by definite genes, and a distinct linkage and cross-over phenomenon have been observed between the factor R and a factor E causing colour in the eye.

Köhler (*Angew. Bot.*, vol. ix., p. 125, 1927), after examining the extensive genetic material left by Fräulein Gravenitz, concludes that it fully supports Salaman's P, R, and D scheme.

Krantz (*Proc. 12th Pot. Assoc. Amer.*, p. 32, 1925) also supports the P, R, and D scheme, but adds a factor A which causes the R or P to produce a self-pattern rather than a splashed one.

The writer is of opinion that fundamentally the P, R, and D scheme holds good, and that there are also colour modifiers whose influence is not yet determined, of which Black's inhibitor H is probably one. The addition of Sirks' factor S may probably be justified in explaining skin colour. In the interests of simplicity it seems permissible to regard the factor D as not only necessary for any colour formation at all, but as responsible for "self" colour, and that multiple allelomorphs D_1 would produce splashed tubers, and D_2 (equivalent to E) give rise to coloured eyes. There seems good reason to believe that the same genes which are responsible for tuber colour are equally responsible for

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colour elsewhere, though the exhibition or inhibition of the same may be due to determiners acting locally.

Tuber Flesh Colour—Anthocyanin colouration red and purple can be developed in the tuber flesh in very variable quantity: in some cases the entire flesh may be blood-red or ink-black. The Mendelian factors determining the colour formation are almost certainly the same as those controlling skin colour. There is, however, good evidence for the existence of an inhibitor which prevents the formation of such colour in the flesh, though present in the skin.

Besides anthocyanin colouration we have the ordinary flesh colour, varying from yellow to white. In this case Fruwirth (*Deutsch. Landw. Presse.*, vol. xxxix., 1912) found yellow dominant. Heribert Nilsson (*loc. cit.*) regards yellow also as dominant, but calls in two pairs of factors. The writer's results support those of Fruwirth; the dominance being imperfect explains the occurrence of intermediate shades.

Tuber Shape—The round tuber is recessive to all long types; the true recessive round is generally shorter than it is broad; the hilum, or point of attachment of the stolon, is sunken between rounded shoulders on either side of it; the crown end is either sunken, or at least flattened. Tubers such as Flourball, Great Scot, Arran Chief, and others, are often called round when in reality they are ovals, and Flourball has been shown (Salaman, *loc. cit.*, 1910) to be heterozygous for length; Epicure and Champion are probably true rounds. Long tubers may be a more or less perfect kidney or cylindrical or finger-shaped; crossed with a round, the F_1 is kidney-shaped.

The two tuber types, the recessive round, and the finger-like long such as is seen in Myatt's Ashleaf, breed true. The cylindrical longs, such as Golden Wonder, are homozygous, the square-shouldered kidney type, such as British Queen, and the oval-like Flourball, heterozygous longs modified by the action of inherited modifiers. Environment reacts on shape to some extent—dry, sandy soils producing the best kidneys and longs, wet, heavy soils favouring the round shapes. The Virus Disease spindle-tuber will produce marked lengthening.

Tuber Eyes—The shallow, smooth eye breeds true; the very deep eye does likewise; the F_1 is intermediate and variable. Dry, sandy soils tend to reduce the depth of the eye, and wet, clayey ones to increase them.

Physiological Characters: *Male Sterility*—The inheritance of male sterility, strictly a physiological problem, has already been dealt with in its relation to aborted anthers.

Maturity—The division of potato varieties into early, maincrop, and late varieties is founded on very definite physiological differences in regard to rate of growth. Genetically little has been done. Müller (*Arb. a. d. Biol. Reichlt.*, vol. xv., p. 177, 1927) concludes that several polymeric factors are involved, and that in grouping seedlings into classes, environmental factors play an important part.

Resistance to Phytophthora infestans—A dominant susceptibility based on what appeared to be a single gene was described by Salaman (*loc.*

POTATO (*Continued*)—

cit., 1910) in regard to the wild hybrid *S. edinense*, or, as it was then called, *S. etuberosum*. Later work showed that this recessive resistance was not to be found in the domestic varieties, but that any resistance found amongst cultivated varieties was merely an expression of late maturity. (See article, Potato, Varieties of.) Vowinckel (*Arb. a. d. Biol. Reichlt.*, vol. xiv., 1926), working with K. O. Müller, found amongst the offspring of crosses between two imported South American varieties and various domestic sorts, certain individual plants the leaves of which withstood artificial infection in the laboratory, whilst the leaves of no domestic variety exhibited a like resistance. It was found that however resistant the foliage might be, the tuber possessed no resistance whatever. Müller (*Zts. f. Pfl. Zucht*, vol. xiii., p. 143, 1928), testing the resistance of seedlings 2 ins. high by infecting them with a drop of an emulsion of conidia, again found no resistance in the seedlings of European domestic varieties. On the other hand, those resistant seedlings which were obtained from the South American crosses were equally resistant to every strain of *Phytophthora infestans* he employed (Müller, *Arb. a. d. Biol. Reichlt.*, vol. xvi., p. 127, 1928). Salaman and O'Connor (unpublished), working on similar lines but using seedlings from domestic varieties as well as the offspring of *S. utile* × domestic, find that true resistance in the domestic seedling does occur as a rare exception in certain families, and have isolated such, together with several resistant plants, from the wild-domestic cross families in F_3 and F_4.

Müller (*loc. cit.*, 1930) has now elaborated a scheme of inheritance of resistance to Blight on the basis of four genes, R_1, R_2, R_3, and R_4, present in one or other of the four tetraploid groups of chromosomes. For the sake of clarity he ascribes resistance values 1, 2, 3, and 4 to each of the genes, and assumes that a zygote is resistant in which the combined value of the R genes$=$12. On such a theory he obtains a remarkably close fit between the observed and the calculated ratios in the families derived from the crossing between his South American parent and domestic varieties.

The position to-day in respect to resistance to *Phytophthora infestans* has thus undergone a very drastic change, and gives ground for the hope that we may yet raise serviceable varieties which are immune to the attacks of Blight. The problem of eliminating the undesirable qualities introduced by a wild species or South American variety, though difficult, is not insuperable. Müller (*loc. cit.*) has shown that the resistance genes are not obviously linked to any of the characters which are *desiderata* for an economic variety. The reverse has not been disproved. Repeated back crossing of the resistant F_1 with suitable domestic types is essential.

The greatest danger to practical success is the rock on which so much genetic work on the potato has already foundered, viz., Virus Disease infection.

Resistance to Wart Disease—The genetics of resistance to Wart Disease was studied by Salaman and Lesley (*Rept. Int. Pot. Conf.*, 1921; and *J. Genetics*, vol. xiii., p. 177, 1923), who determined its incidence by

POTATO (*Continued*)—

growing their seedling families in the highly infected grounds of the National Institute of Agricultural Botany at Ormskirk. The presence of any wart whatever when grown in the open was considered as evidence of positive susceptibility. The results showed that susceptibility was recessive. The hypothesis put forward is somewhat complicated, but has so far not been impugned. They assumed:

1. Two factors, X and Y, each of which can produce immunity in the presence of a complementary factor Z.
2. If X and Y be present together, they can produce immunity whether Z is present or not.
3. That there are two inhibitors, A and B, which would appear to be both necessary to inhibit X or Y, but incapable of inheriting X and Y when both are present.

The fact that families were isolated which were 100 per cent. immune, as well as others in which the ratio of immunes to susceptibles was 15 : 1, 3 : 1, and 9 : 7; and that immune seedlings were extracted from certain selfed families of susceptible varieties, proves that no very simple scheme will fit the facts.

Glasshouse tests made under the optimum conditions of moisture and temperature will lead to the infection of almost any of our immune varieties, causing in some but a minute, and in others, like Abundance and Snowdrop, a bulky tumour. The genetic relations underlying such conditions have not been attempted. It appears that the field reactions which hold good for Europe and America do correspond to a definite genetic structure of the nature sketched above.

Inheritance of Yield—That the quantity of a plant's reserves, which in the potato are stored in the tuber, should be controlled in some way by genetic factors no less than by external environmental influences is tacitly assumed by competent raisers. The difficulty of putting the question to the test lies in the fact that the mere weighing of the crops produced by a first-year seedling leads nowhere. What is required is some measure which expresses the relation between the size of the plant, *i.e.*, the area of its leaf surface and the weight of the crop, and thus expresses the relative capacity of the plant to store starch, etc. Such a measure must of necessity be a purely subjective one, if large numbers of seedlings are to be scored for crop in a season. Salaman (*Imp. Bot. Conf.*, London, p. 40, 1924), employing such a method, graded the relative crops into zero, *i.e.*, no crop, and four ascending degrees of "relative cropping," and expressed the resultant values derived from any given family of seedlings in a curve. It was found that whenever a given variety was selfed, its seedlings always gave a constant curve. Such curves could be classed as high, medium, low, etc., or, more exactly, as Curves I. to VII., according to the percentage of good, medium, poor, etc., crops the individuals bore which formed the family.

Further analyses (Salaman, *Verhdl. Inter. Kongress f. Vererb.*, Berlin, vol. ii., p. 1240, 1927), involving some 400 families made up of 25,000 seedlings, led to the view that there are probably two genes concerned, A and B, which have a cumulative action in inducing storage of reserves, *i.e.*, in producing tubers, and that certain wild tuber-bearing

POTATO (*Continued*)—

types, such as *S. utile* and *S. edinense*, possess one or more inhibitory genes which are dominant to A and B. If by mutation or otherwise such an inhibitory factor drops out, then the capacity to crop makes its appearance. The evidence for such inhibitors is good, and the evolution of the cultivated potato must presumably have been preceded by the loss of one or all inhibitory genes.

Inheritance of Vigour—By vigour is meant the production in the first-year seedling of strong, bushy, and vigorous plants. In the second year such vigour may have been all dissipated by virus infection. The more vigorous the parents, the higher the proportion of vigorous offspring; a cross of two related inbred F_4 lines, each of low vigour, results in a family exhibiting considerably more vigour than do the selfed families of either parent. Vigour in the potato is undoubtedly influenced by heterosis, and it is for that reason that the more vigorous varieties are those with most colour in their tuber, stem, and flower. That vigour is inherited is certain, but it would be idle to try and frame a scheme for such.

Relation of Vigour to Yield—It was evident from those experiments, where the inheritance of vigour was studied at the same time as that of yield, that the genetic basis of cropping and that of vigour are quite distinct and unlinked. As any new variety must combine both high yield and high vigour, it was possible to ascertain exactly how often such a combination occurred in the seedling families arising from the selfing or crossing of standard varieties. In a random cross between modern domestic varieties, such a genetic combination might be expected in about 10 per cent. of the whole family, so that of any 100 seedlings of a good stock not more than ten are eligible for selection, and in this reduced number must be found such qualities of shape, colour, maturity, tolerance of virus disease, taste, and the like, as will commend it. The birth of a new variety possessed of all the most desired qualities must indeed be a rare event.

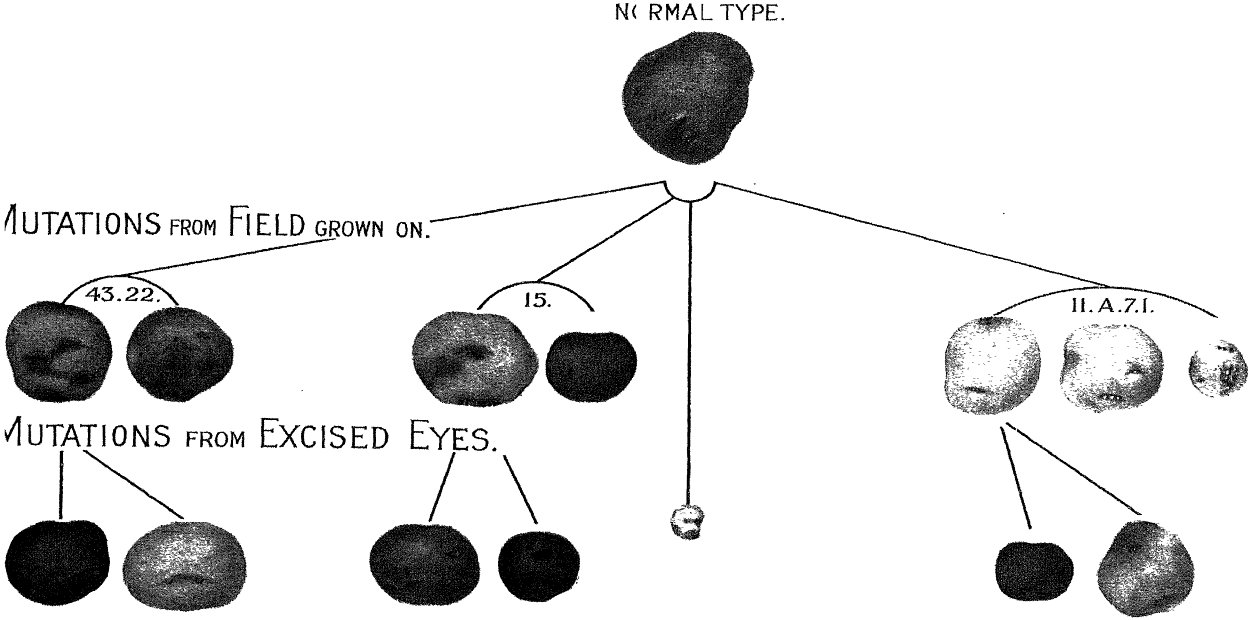
Mutations and Chimæras—The occurrence of sharp changes in flower and tuber colour has been frequently described; occasionally the latter has led to the establishment of a new variety; *e.g.*, a purple-splashed sport of the white-tubered Rector of Woodstock was introduced as Harlequin by Messrs. Sutton and Sons in 1888. The self-coloured Red King Edward is a mutant of King Edward; Sefton Wonder is a russeted sport of Great Scot. Of scientific rather than economic interest is the occasional sporting of the continuous coronate corolla common to all the domestic varieties to the stellate type, which is normal to many wild species, such as *S. commersonii*. In general, mutations have but a local effect, be it on tuber, flower, or leaf; occasionally, as McKelvie (*Rept. Internat. Pot. Conf.*, London, p. 35, 1921) showed, they may affect both tuber colour and foliage. Salaman (*J. Genetics*, vol. xv., p. 267, 1925) showed that the mutation may go still farther and affect the germ cells. A new light, however, has been shed on the whole series of phenomena by the work of Asseyeva (*J. Genetics*, vol xiv., p. 1, 1928), who has proved by the ingenious device of paring

POTATO (*Continued*)—

away the superficial layers of the tuber eye and promoting re-growth, that in the domestic potato the formation of chimæras is quite common. In general, one must assume that a somatic mutation affecting tuber colour, leaf development, or the like, has occurred in a cell in the growing point of a vegetative bud. Confining ourselves to tuber colour mutation, we learn from Asseyeva (*Bull. Appl. Bot.*, Leningrad, 1930), who has studied thirty-seven such, that the occurrence of "gain" mutations, *i.e.*, white to red or purple, and red to purple, is about as common as the "loss," viz., those from red to white or purple to red or white. A mutation having occurred, it appears that the normal and mutated tissues may assume definite positions, so that the epidermal layer may be made up of mutated cells and the subepidermal of normal ones. In such a case, assuming that the original tuber was white, true new mutated tubers will appear, say, as red-skinned with white areas generally situated about the eyes, *i.e.*, it will be a red, splashed with white. The stem of such a mutant will contain no more pigment than the original, because stem colour is always subepidermal. Selfed seedlings of the mutant will be all white-tubered as those of the normal, because the gametes are derived from the subepidermal cells. Let us assume now that the arrangement of the mutant tissue in the growing point is such that the mutated tissue is subepidermal and the normal is epidermal, then the new mutant tubers will be white with coloured brows and eyes, *i.e.*, a splashed white, and the stem will be deeply coloured. Selfed seedlings will now exhibit a certain proportion of coloured tubers as well as whites. Finally, if the mutant tissue is several layers thick and occupies both epidermal and subepidermal situations, then the mutant tuber will be wholly coloured, the stem deeply pigmented, and the seedlings, as in the former case, will be some coloured and some white. Common to all these types of chimæra is the fact that the seedlings are always either self-coloured or colourless; they are not splashed, though they may have "picked" eyes if the parent had. The splash colour of the mutant is due to the unequal part played by the epidermal and subepidermal tissues in supplying the outer coatings of the tuber, especially in the neighbourhood of the eyes.

That the mutant plants never give rise to splashed seedlings is due to the fact that inasmuch as the original mutation is one affecting either the elimination or the creation of a colour gene, the gamete will either have or not have such a gene in its chromosomes. If it has, then it will give rise to a coloured zygote, presuming the other necessary genes are present. It will be a self-coloured zygote, for to be other, it would be necessary to induce a mutation in those genes which control colour distribution. In addition, Asseyeva has studied a peculiar class of colour patterns affecting the colour of the eye and its immediate surroundings, such as may be found in some South American varieties: her results suggest that the problem may in these cases, if they are indeed chimæras, be far more complex than that described above, for the evidence would suggest that such chimæra-like patterns are carried by the gametes.

ATE XIX



Row 1.—A normal self-colour ple tuber of Arran Victory.
Row 2.—All tubers in this row erived from plants raised from nutant tubers of Arran Victory found in th or p
To left, 43.22. Two tubers from on : the first a purple " splash " on a white background, the other a purple " spl on a purple
In middle, 15. Two tubers from o nt : the first a purple " splash " on a white ground, the other a normal " t tuber
To right, 11.A.7.1. Three tubers ne plant : the first colourless ; he second with a trace of purple on a bro in a he thir
streaks of colour amounting to a " n."
Row 3.—The plants in this ro all derived from tuber cores fur ished with one eye only, which eye has be xcise arying
From 43.22 : a normal self-coloured tuber from one plant, and a co ourless tuber from another.
From 15 : a normal self-coloured r eddish-purple type tuber from ne plant, and a super-purple, self-coloured from r.
From 11.A.7.1 : two tubers from th plant—one a normal self-colo ed purple, the other a diffusely self-colour rple, ash-lik
ions of colour. From the normal a small " splashed " tuber bor on a plant derived from an excised eye o ype t

POTATO (*Continued*)—

Perhaps the most important feature of Asseyeva's latest work is the proof that a "wilding," a variant in which the plant is dwarfed, the leaves altered in shape and complexity, the flowers absent, the tubers lengthened, reduced in volume, and greatly increased in number, is probably an example of a chimæra, and by the method of excision of eyes it may be converted to the normal. "Wildings" are very common amongst domestic varieties, especially in King Edward, Arran Chief, and Up-to-date.

Recent work on similar lines by Salaman (*loc. cit.*, 1930) confirms the main line of Asseyeva's thesis, but he differs from her in regarding the arrangement of the mutated and unmutated tissues as being only chimæra-like in a general sense, and that the two types of cells are not relegated to exact layers, but have a much more irregular distribution. In the same communication, a general account of potato mutations will be found.

Asseyeva's work on leaf mutation is of the greatest interest, and its scientific value is so great that the original paper should be consulted. The fact that chimæra-like mutations are so common in the potato—Asseyeva has collected some 150 examples—may be associated with its polyploid nature.

References.—Fruwirth, "Bibliographica Genetica," vol. i., 1925; Matsura, "A Bibliographical Monograph on Plant Genetics," Tokyo, 1929; Salaman, "Potato Varieties," Cambridge, 1926. R. N. S.

POTATO, FUNGUS AND BACTERIAL DISEASES OF THE, The Potato Blight (Late Blight) (*Phytophthora infestans*)—The Potato Blight, which is of South American origin, as in the case of the potato itself, has been established in Europe since 1845. In the July and August of that year the disease first attracted general attention in Belgium and Holland, and before the end of the season was successively reported from every country in Western Europe, from Norway to Bordeaux, and from Poland to the Atlantic. The "fatal malady" was first noticed in England in the Isle of Wight on August 16, and it appeared to sweep from one end of England to the other and into Scotland within two weeks. By September 13 it was reported near Dublin, and when the crop was dug no part of the country was found to have escaped. The panic which ensued is difficult to describe. The loss in 1845 was estimated at one-quarter to one-half or more of the crop, but this was only a foretaste of what was to come, for in 1846 the disease reappeared early in July, completely blackening the crops over large areas of the country within three weeks. The destruction everywhere was very great, more particularly in Ireland, where Lord Lansdowne estimated that eight- to nine-tenths of the crop was destroyed.

It is now known that the same Blight had devastated the United States in 1843, and Lower and Upper Canada in 1844 (with very serious results in Nova Scotia and elsewhere), spreading inwards from the Atlantic towards the west. There, also, it was a new introduction. Furthermore, a strange potato disease had been present in St. Helena

POTATO (*Continued*)—

for several years before 1845, and it is likely that the original introduction to Europe was by way of one or other of these countries. It cannot now be maintained that this took place once for all in 1845, because the disease could not have spread to the extent it did from one centre in a single season. The conclusion is unavoidable that local centres of infection must have existed throughout a large part of Europe for a few years previously. There is proof that the Blight was known in Belgium in 1844, and probably since 1842, and evidence is available which may be held to show that it was present in Norway and Denmark as well as in England, Scotland, Ireland, and the Isle of Man, between 1841 and 1844. Similarly, Blight had been present near Boston, Mass., at least as early as 1842, which was a year before the first general outbreak in the United States. Attempts to show, however, that the Blight had already been present in Europe many years before 1840 are opposed to the views of the best contemporary observers.

The life history of the responsible parasite, *Phytophthora infestans*, has long been known in essentials. The parasite invades the leaf, directly or through a stoma (breathing pore), and grows within it, producing in three to five days the familiar, almost black, dead blight spots. Around the margin of these spots on the lower leaf surface, the fungus fructifies in moist weather in the form of a delicate greyish mildew, on which spores are borne. These may germinate in the presence of water in two ways, either directly, or more usually indirectly, when each gives rise to about a dozen secondary spores capable of independent motion. Under favourable conditions of temperature and moisture, each of these bodies is capable of causing a new infection, with the result that all the foliage may be killed prematurely three to four weeks after the first outbreak. The leaves become more susceptible after the flowering stage is passed. The disease may also invade the stalks, which become rusty-brown and brittle at the points of attack, but the tubers are not invaded through this channel. Tuber infections take place through the agency of spores washed down from the leaves through the soil, entry being usually through lenticels. Tubers grown in clay soil are more subject to attack than those grown in sandy soil. The rot is normally of a dry type (except under wet conditions), the surface showing a pock-marked brown appearance, and the flesh a reddish-brown discolouration which does not usually penetrate deeply (Plate XX, Figs. 1 and 2). Secondary rotting organisms not infrequently set in afterwards and produce a wet rot.

The parasite hibernates in blighted tubers, and a proportion of these, either when planted again in error or otherwise left in the ground, produce weak plants into which the fungus makes its way, and on which it fructifies. In this way the attack on the aerial portions of the plant is again initiated. The primary outbreaks which result in this way are frequently found on the site of potato pits and in gardens, where blighted tubers are usually left lying around. The fungus appears to have almost lost its power of producing rest-

PLATE XX

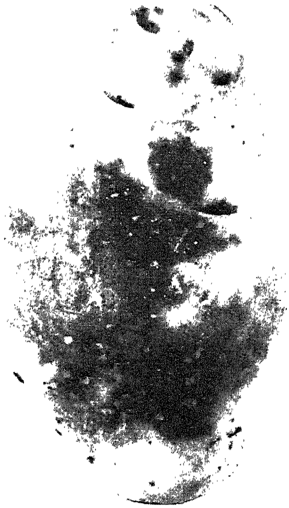


FIG. 1.—POTATO BLIGHT.
External view.

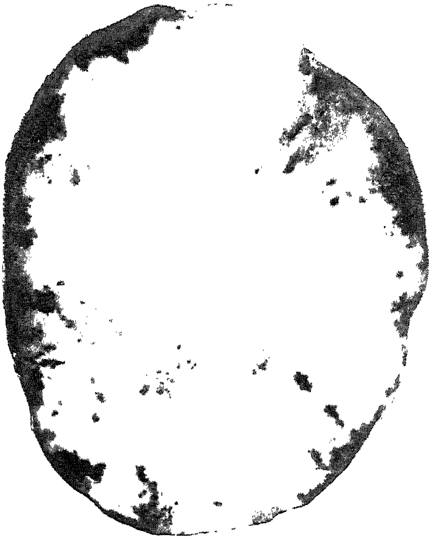


FIG. 2.—POTATO BLIGHT.
Internal view.

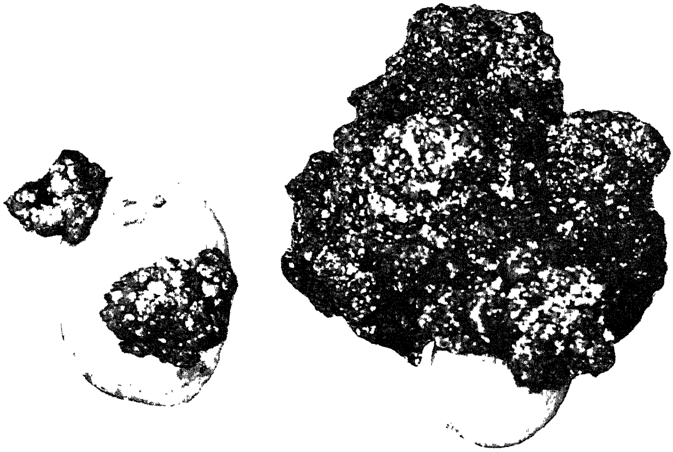


FIG. 3.—POTATO WART DISEASE.

To face p. 938

POTATO (*Continued*)—

ing spores; and the existence of soil infection has not been established.

Continued wet or unsettled showery weather, with a fairly high temperature (over 60° to about 70° F.), with moderately cool, dewy nights (54° F. optimum), which favour indirect germination of the spores, are most favourable for the disease. Hence the severity of the attack in Ireland, the south-west of England, and elsewhere. Most damage is done in years in which there is an excessive rainfall from the latter part of May to July. Temperatures above 75° F. check the parasite and may kill it, if prolonged. The following combination of weather conditions is believed in Holland to be precedent to an outbreak, and wireless warnings are accordingly issued in that country when they occur: a night temperature below the dew point for at least four hours, with a minimum of 50° F. or more; cloudiness on the following day of 0·8 or higher, and a rainfall of at least 0·1 mm.

There is frequently a second and very serious phase of tuber infection at the time of digging. This originates from spores which may still be present on the partly green foliage, or spores present in the surface layers of soil, where they can survive for two to three weeks. The slight wounds or abrasions more or less inevitable in digging greatly favour infection. The later the attack and the greener the foliage at this time (granted that Blight is present), the more disease develops in storage. Infections contracted in this way show up within four weeks. The Blight does not spread from tuber to tuber in clamps, pits, or elsewhere. (See under Black Leg.)

Control.—Control measures have been unusually well worked out. Reliance was originally placed on resistant varieties, and one result of the introduction of Blight was to give an impetus to potato breeding. Resistant potatoes are, however, almost invariably very late in maturing and poor in quality, added to which they gradually lose their resistance, becoming at the same time earlier and better in quality. These changes are the result of increasing virus infection in the stocks. The well-known Champion potato is an excellent example. In the severe epidemic of 1879 it proved itself outstandingly Blight resistant, and in consequence was grown in Ireland for more than thirty years almost to the exclusion of all other varieties. Its resistance, however, gradually declined, until it eventually became looked upon as notoriously susceptible. The reason for this decline was made apparent for the first time when a virus-free stock of Champion was built up, for this was found to have recovered its resistance to Blight. Since the introduction of spraying, growers have universally preferred somewhat susceptible varieties such as Up-to-Date, King Edward, and Green Mountain, which are more suitable for market purposes. (See Potato, Virus Diseases of; Potato, Genetics of; Potato, Varieties of.)

The application of a mixture of copper sulphate and quicklime (Bordeaux mixture), or copper sulphate and washing soda (Burgundy mixture), to the leaves to prevent infection goes back to the year 1888. The practice was immediately taken up, more particularly

POTATO (*Continued*)—

in Ireland, where it is calculated that 90 per cent. of the main crop is now sprayed, and in most other places where blight is severe. The resulting increase in yield averages 2 tons per acre. Bordeaux mixture (2 per cent.) is made to the formula: 8 lbs. copper sulphate, 4 lbs. quicklime, and 40 gallons of water, 2 per cent. Burgundy mixture, consisting of 8 lbs. copper sulphate, 10 lbs. washing soda, and 40 gallons of water. The two mixtures are of equal value, and 1 per cent. solutions are practically as effective as 2 per cent. In Ireland, Burgundy mixture is universally preferred, and it is now customary to use the weaker solution for the earlier applications (one or two), and the stronger for the last, since this "sets" the plants—that is, it checks them slightly and prevents the growth of new foliage. Spraying must be begun before Blight appears, say by June 15, or earlier in Ireland and south-west England, and by July 1 to 15 in the eastern districts. Repetitions follow after three weeks. A fine mist, which covers the leaves above and below without making them drip, is essential. Knapsack machines, and traction- or engine-driven sprayers covering four or more drills, are used, the first and last being usually most satisfactory. The tendency in America is to use petrol-driven pumps working at pressures up to 200 lbs. per square inch. The quantity of mixture applied per acre varies from 120 to 160 gallons.

There has been a considerable tendency in recent years to replace liquid sprays with dry applications, which are dusted on the foliage (preferably when it is moist) at the rate of 20 to 30 lbs. per acre. The dusts are proprietary materials of varying composition, and although they are neither quite as effective nor as economical as liquid sprays, their use is growing on account of the greater ease of application. (See Insecticides and Fungicides.)

To dig the crop while there is still Blight on the partly living foliage, or to cover potatoes even temporarily with the latter, is to invite a serious amount of storage rot, and the more roughly the crop is handled the more will rot develop. It is difficult to lay down a general rule, but the crop is usually safer if left in the ground until two weeks after the stalks are entirely dead. If rot is feared, it can be picked out a month afterwards, after which the tubers should keep safely if stored in dry, well-ventilated pits.

Wart Disease (*Synchytrium endobioticum*)—This now well-known disease (sometimes called "Black Scab") was first described in Czecho-Slovakia in 1896, but there is reason to believe that it was known to growers in Lancashire and Cheshire for some decades previously. Its origin has not been satisfactorily established. In Great Britain it is most widespread in the northern and midland counties, in Wales, and in the midland and southern counties of Scotland. There are isolated outbreaks in Ireland, particularly in the north. No country in north-western and central Europe is free from the disease, and outbreaks have occurred in Newfoundland, the United States, and South Africa. Wart Disease is "scheduled" in all parts of the British Isles, and every outbreak must be notified to the proper Agricultural Authorities.

POTATO (*Continued*)—

This disease causes characteristic cauliflower-like excrescences on the tubers, which may be small and nodular (in which case it will be seen that they arise from an eye), or may cover a large part of the surface (Plate XX, Figs. 3 and 4). These are first whitish in colour, but later they turn black and decay. The disease continues to develop in the pits. Although a large part of the crop may be rendered useless, the vigour of the plant does not suffer, but warts sometimes develop on the stems and lowest leaves. The disease is most severe in wet years and in moist situations.

The fungus responsible for Wart Disease is of a low type, and has a simple life history. Free-swimming spores, arising from resting bodies present in the soil, penetrate into superficial cells of the tubers, stems, or leaves, which are not provided with a corky wall, and produce within them a number of spore cases, which quickly liberate further similar spores to the exterior. These spores are short-lived, and their function is to propagate the disease during the summer. Under the stimulus of infection, abnormal cell multiplication takes place, which eventually leads to a warty outgrowth. Later in the season thick-walled resting spores are formed within cells which have been infected by a body formed by the union of two free-swimming summer spores. The resting spores find their way to the soil when the warts decay. They are extremely resistant, and are known to remain alive and dormant in the soil for at least twelve years; indeed, there is still no record of the disease having died out of heavily contaminated soil. A few plants related to the potato, including many varieties of tomato, the black and woody nightshades, and henbane, have been proved to be susceptible.

Control.—The disease does not spread through the air, but is carried from place to place in infected tubers or contaminated soil. Any agency by which soil is transported may convey the disease, among which may be mentioned water, implements, the feet of animals and man. Warted tubers are the most dangerous agents of dispersal, but tubers even of immune varieties, and other plants, such as cabbages, may carry infection in the soil adhering to them. Sweepings from potato stores and domestic refuse are further likely sources of disease. Manure made by animals fed on raw diseased tubers is also infective. Every care should be taken to prevent clean land becoming contaminated. The best way of dealing with an outbreak is to lay the land down to permanent pasture for a long term of years. No practical method of sterilizing infected soil has yet been discovered.

The discovery of immune varieties has provided a perfect means of control, and the disease will lose most of its significance when it becomes universally distributed, although that time is not yet. Efforts to produce new immune sorts have given a great impetus to potato breeding, and the number of such varieties now available in England exceeds two hundred. The situation elsewhere is not so satisfactory, but it is fortunate that some of the most important American varieties, such as Green Mountain and Irish Cobbler, do not succumb to the disease. At the same time no immune varieties have yet been pro-

POTATO (*Continued*)—

duced which are quite the equal of Epicure, Up-to-Date, and King Edward. The best known of those available are Di Vernon (*early*), Great Scot (*mid-season*), and Kerr's Pink, Majestic, and Arran Banner (*late*). (See Potato, Genetics of; Potato, Varieties of.)

Black Leg (*Bacillus phytophthorus*) and **Soft Rot**—Black leg, which is one of the few plant diseases caused by bacteria, is universally distributed in Great Britain and Ireland, Europe, and elsewhere. It causes the death of individual plants in the field, and may be connected with "missing" and uneven stands, besides causing a tuber rot. Affected plants (or individual stalks) become flaccid, with up-rolled, yellowish leaves; and the presence of the disease is easily verified by pulling them up and finding a dark rot in their underground portions. A slimy whitish rot, in which cavities develop, is produced in the tubers, beginning at the heel end and rapidly destroying them. The disease does not spread epidemically from plant to plant, but it is known to be carried by the tubers, and on this account is particularly undesirable in fields grown for seed purposes (Plate XXI, Fig. 1).

Knowledge concerning the disease is still unsatisfactory in a number of ways, notably in the matter of soil infection, and the possible rôle of caterpillars, etc., in initiating the disease in the fields. The larvæ of the Corn Root Fly, which feed on the planted tubers, have been found to be efficient inoculating agents in America. It is also uncertain to what extent Black Leg is responsible for the serious soft rot which sometimes rapidly spreads through pitted potatoes, at times to such an extent as to cause the pits to cave in.

Control.—The use of sound seed from healthy crops (certified seed or its equivalent), coupled, if necessary, with the complete removal of diseased plants three or four times during June, July, and August, is effective. Early planting and wet soil favour the disease. In America it is usual to disinfect the seed tubers (which, owing to the climate, are usually unsprouted in spring), using corrosive sublimate solution 1 : 2000 for one-and-a-half hours, or formalin solution 1 : 240 for two hours, or more recently hot formalin solution 1 : 120 at 123° F. for four minutes, for this and other diseases such as Scab and Black Scurf (*q.v.*). None but dry, healthy potatoes should be placed in storage, and the pits should be ventilated, cool, and well-drained. Tubers in which blight is present are particularly likely to be attacked, and the Soft Rot may spread from them to other healthy potatoes in the pit.

Dry Rot (*Fusarium cæruleum*)—This disease, which is of universal occurrence, is confined to the tubers, in which it causes a Dry Rot during the storage period, and sometimes a decay of cut sets after planting. It develops both in pits and houses, and dry conditions do not stop its progress. Tubers become more subject to the disease as the spring approaches, and the first-early varieties are particularly susceptible, especially May Queen, Duke of York, and Ninetyfold. The Rot is somewhat similar to Blight rot, but may be distinguished from it by the development of wrinkles around the shrunken decaying

PLATE XXI

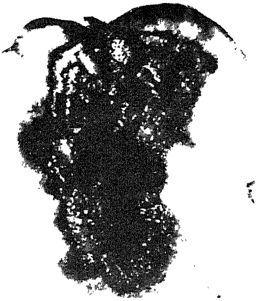


FIG. I.—POTATO BLACK LEG, TUBER ROT.

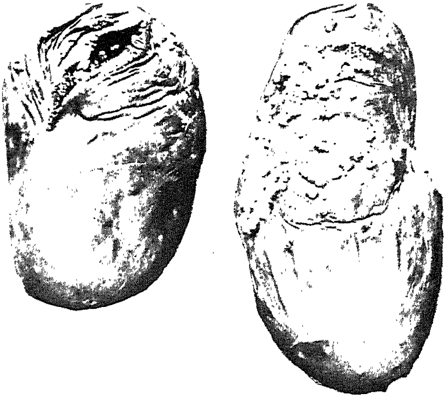


FIG. 2.—POTATO DRY ROT.

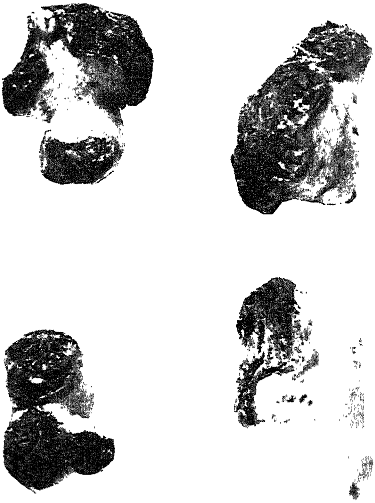


FIG. 3.—POTATO POWDERY SCAB, CANKER STAGE.

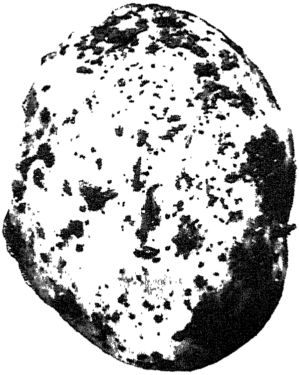


FIG. 4.—POTATO BLACK SCURF ON TUBER.

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portions of the tubers (particularly under dry conditions), the presence of cavities in the flesh, the abundance of mould growths within and without the decayed areas, and the final mummied condition of the tubers (Plate XXI, Fig. 2). Dry Rot never occurs in the field in autumn.

Control.—The disease principally attacks wounded tubers or those already suffering from Blight, so that all possible care should be taken in sorting and handling. First-early varieties are better greened and stored in sprouting boxes, and they should be picked over periodically. The disease may persist in storage houses and boxes, to obviate which, in the case of serious outbreaks, they may be disinfected with 2 per cent. copper sulphate solution. Diseased tubers should be cooked or destroyed. When the the crop has suffered from Dry Rot it is dangerous to cut the apparently healthy tubers for seed, more particularly if they have to be stored for any time before planting, or if the weather is cold and growth is likely to be slow afterwards.

MINOR BLEMISHES AND DISEASES—**Common Scab** (*Actinomyces* sp.) may occur as a few isolated spots or may cover a large part of the tuber, in which case it becomes serious. Contrary to general opinion, it is a parasitic disease, which may originate from the soil or from affected seed pieces. The disease is most severe in dry, alkaline soils, or those to which lime or ashes have been added, and flourishes best at high temperatures (optimum 70° F.). Little can be done to reduce the attack, but the ploughing in of green crops is helpful. In small culture, the liberal use of lawn mowings as manure has an excellent effect. Seed treatment (see under Black Leg) is recommended in America, as well as manuring with sulphur, but neither is necessary as a rule here.

Powdery Scab (*Spongospora subterranea*) is a disease principally of the tubers. Although present throughout the British Isles and elsewhere, it is practically of no consequence in commercial potato production, but a serious canker form of the disease occurs in the wetter portions of Ireland and Scotland, and elsewhere in wet seasons. The cankers have a superficial resemblance to Wart Disease, but they can usually be distinguished by the presence of a brown powder in their open or hollow truncated tops (Plate XXI, Fig. 3). The worst outbreaks occur where rotation is not practised, and the disease is also seed-borne.

Black Scurf (*Corticium Solani*) is a fungus disease which takes many forms. The parasite frequently attacks the sprouts in the soil when growth is slow in spring, killing their tips and resulting in late plants with a number of weak shoots. The attack on the underground portions of older shoots causes a certain stoppage of the downward flow of manufactured food which manifests itself in a rolling of the topmost leaves (to be distinguished from primary Leaf Roll), and sometimes in the production of small tubers at soil level, or even on the haulms. The delicate white girdle sometimes seen on stalks

POTATO (*Continued*)—

just above ground level is the fruiting stage of the fungus. Finally, the resting stage of the parasite occurs as detachable black specks on the surface of the tubers (Plate XXI, Fig. 4). The attack originates from this source or from the soil. Seed treatment with corrosive sublimate (see under Black Leg) is widely recommended in America as a means of control.

Skin Spot (*Oospora pustulans*) causes a slightly pimpled appearance on the surface of potato tubers. It is harmless unless the eyes become involved, when missing not infrequently follows. Seed potatoes should be examined for the presence of this disease before purchase.

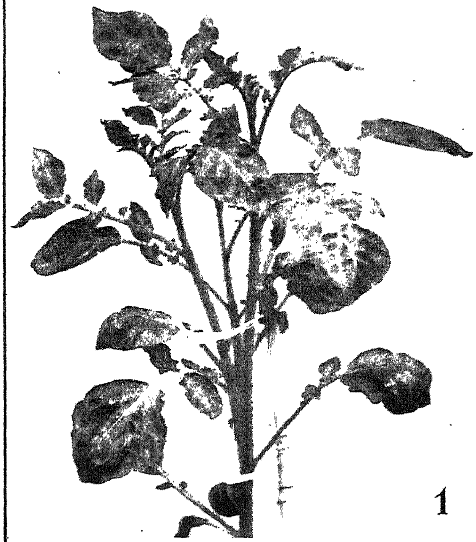
One or two other diseases may be mentioned, although they are usually of little or no account except in restricted localities. **Stalk Break** (*Sclerotinia sclerotiorum*), which is sometimes more severe than Blight in the West of Ireland, causes the fracture and complete death of the stalks in summer; while **Pink Rot** (*Phytophthora erythroseptica*) is a soil-infesting disease mainly affecting the tubers, which it rapidly destroys, beginning as a rule at the heel end. P. A. M.

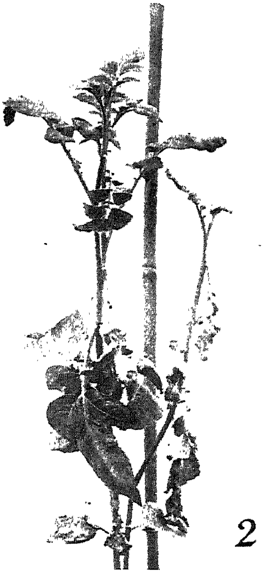
POTATO, VIRUS DISEASES OF THE—Virus Diseases of Plants and How they differ from Other Classes of Plant Diseases—Diseases of agricultural crops, and, indeed, of plants in general, may, broadly speaking, be classed into three main groups: firstly, diseases which are due to the presence in the plant host of harmful bacteria, such a disease as "Blackleg" of potatoes, for example; secondly, disorders due to the action of microscopic fungi such as Bunt and Rust of cereals; while the third class consists of a group of maladies of unknown cause, termed "Virus Diseases," which are the special subject of this article.

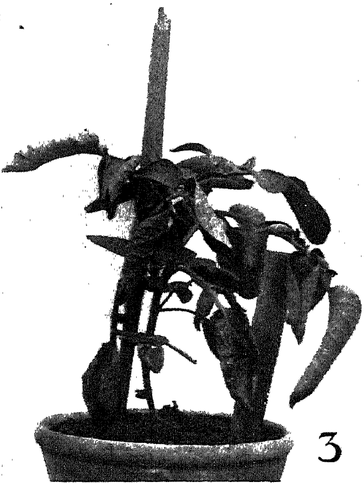
There is little doubt that the virus diseases of both plants and animals are becoming of primary importance, and in time will demand as much consideration from pathologists as diseases from the other two causes do at the present moment. Plants of all kinds, in both temperate and tropical regions, are affected with disorders of the virus type. The following list gives some idea of the wide range of crops which suffer from virus diseases: Bunchy Top of bananas; Mosaic of tobacco, sugar-cane, and sugar-beet; Streak of maize; rosette of peanuts; Yellows of asters; Curly Top of beet (*q.v.*); Leaf Roll and Mosaic of potatoes; Mosaic of tomatoes, cucumbers, etc. (*q.v.*), and many others. It will not be out of place to mention here a few virus diseases attacking animals, including man. The most well known virus affecting animals, of course, is foot and mouth disease; while probably influenza, scarlet fever, yellow fever, and small-pox are examples of the same group affecting man. In all, upwards of one hundred different virus diseases have been described.

It will be convenient first to consider some of the main characters of virus diseases of plants; although the symptoms of these diseases may differ widely, yet it will be found that a thread of similarity runs through the group, and certain definite characteristics justify their

PLATE XXII







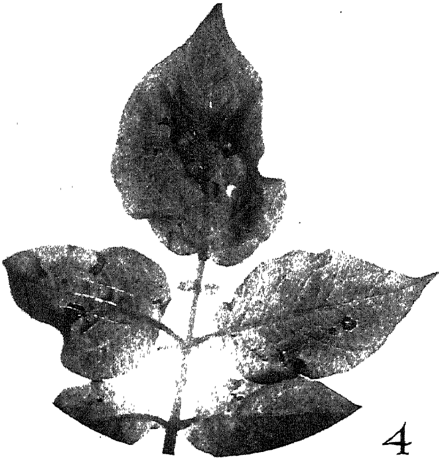


FIG. 1.—POTATO CRINKLE. Note the mottling and distortion of the leaves.

FIG. 2.—LEAF DROP STREAK. Note how the leaves shrivel and drop down.

FIG. 3.—POTATO LEAF ROLL. Note the rolling of the leaves and the stunting of the plant.

FIG. 4.—STREAK. Note the brown spots appearing on the leaves; these are often preliminary symptoms to the development of the disease shown in Fig. 2.

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POTATO (*Continued*)—

segregation into a class apart. One important property shared in common by plant viruses is their power of infecting healthy plants, and it is their ease of spread in the field which constitutes one of the chief dangers of this class of disease. How the virus is disseminated from plant to plant in the field is dealt with in an ensuing paragraph. Again, in 1892 Iwanowsky found that the infective principle which causes the Mosaic disease of tobacco was still retained by the juice of a diseased plant after passage through a porcelain filter, and that healthy plants could be infected from such a filtrate. This shows that the constituent particles of a virus can pass through the pores of the filter candle, which are yet too small to allow passage of the smallest bacteria. This capacity to pass through the pores of a filter candle is another important characteristic of virus diseases. Whether all plant viruses are filterable is not yet known; and where, for instance, the infective entity cannot be inoculated into a plant by needle scratch, as in potato Leaf Roll, it is not easy to determine this point.

It has been said that the causal agent of virus diseases is undiscovered; this is partly due to the difficulties inherent in dealing with an entity too small to be seen with the highest magnification, and partly to the fact that it has not yet been possible to culture the virus on artificial media outside the plant host. Again, plant virus diseases are characterized by their systemic nature—that is, the occurrence of the infective principle in every organ and part of an affected plant, with the probable exception of the seed. Such systemic infection is very rare in plant diseases due to causes other than virus, where it is usual for infection to be localized.

The outward manifestations of virus diseases in the plant host are very varied. They take the form, sometimes, of distortion of the leaf, such as rolling, crinkling, or puckering; sometimes of discolourations of leaf and stem, like mottling or streaking, and often regular concentric rings with a central spot develop on the leaves (K. M. Smith, "Studies on Potato Virus Diseases," No 4, *Ann. Appl. Biol.*, xvi., No. 1, 1929). Another type shows destructive lesions on leaf and stem which may bring about the death of the whole leaf and often of the entire plant.

While the foregoing is a brief description of some of the external symptoms of plant virus diseases, mention must be made of a certain microscopical symptom within the plant which seems peculiar to this type of disease. Microscopical examination of sections through the leaves or stem of virus-infected plants reveals the regular occurrence within the cells of certain minute bodies known collectively as "intracellular bodies" or "X bodies." These are of characteristic appearance and present an aspect superficially similar to certain protozoa. At first these bodies were considered to be living organisms closely connected with the cause of virus diseases, and there are still virus workers who hold this opinion. It seems more probable, however, in the light of recent work (J. Henderson Smith, *Ann. Appl. Biol.*, xvii., 1930; K. M. Smith, *Ann. Bot.*, 1924; I. Hoggan, *J. Agric. Res.*, xxxv. 7, 1927), that these X bodies are products of the cell cytoplasm,

POTATO (*Continued*)—

and therefore effects, rather than causes, of the disease. (See Virus Diseases.)

Some Common Potato Virus Diseases—It has been briefly shown what a variety of plants are affected by virus diseases. In Great Britain chief economic importance attaches to the viruses attacking the hop, the tomato, and the potato, and it is with the last-named plant that this article is chiefly concerned.

There are many virus diseases of the potato; some of them are definite and characteristic, with well-marked symptoms, others are less definite, and some are probably complexes of more than one virus. The commonest and most widespread potato virus is undoubtedly that known as Mosaic. It is so widespread as to be present in over 90 per cent. of the potato stocks of England, and in certain varieties—"Golden Wonder," for example—it is exceedingly difficult, if not impossible, to find any plants free of the virus. The manifestations of Mosaic are not very obvious and might easily be missed by an untrained observer. They take the form, for the most part, of a slight but quite definite mottling of the leaves, which may or may not be accompanied by shallow indentations or ruffling of the leaf surface. Although the most widespread potato virus, it is probably less destructive in its effect on the yield of tubers than most of the other virus diseases of the potato.

Another disease of the mosaic type, and closely approximating to it in its symptom expression, is that known as Crinkle. In this disease the mottling is much more distinct, and, as the name implies, there is considerable crinkling and distortion of the leaf surface, while the margins of the leaves are waved; this disease is more severe than the foregoing mosaic, and is probably a mixture of viruses (Plate XXII, Fig. 1).

A third disease of the mosaic group is known as "Streak," and in its outward manifestation approaches much more certain bacterial diseases than do the majority of potato viruses. In this case the chief symptom is the development of black or reddish streaks upon the stem and along the veins, and spot-like lesions on the leaves (Fig. 2). These lesions may or may not develop into what is known as Leaf-drop Streak, where the leaf is destroyed and the whole plant frequently killed. Streak is the most perplexing of all the potato viruses, and its exact connection with the Mosaic and Crinkle diseases, with which it is frequently associated, has not yet been determined.

Another potato virus of a different type, and one of considerable economic importance when it occurs in quantity, is known as Leaf Roll, so called from the tendency of the leaves to roll up in a characteristic manner (Fig. 3). Such leaves are chlorotic, thicker than normal, and are harsh and leathery to the touch. The first sign of the development of Leaf Roll in an affected plant is the appearance of a characteristic pallor on the younger and uppermost leaves; they then begin to roll, usually from the base of the leaf upwards and inwards; this condition is known as "primary" Leaf Roll. Later in the season, or the following year if infection occurs late in the summer, the

POTATO (*Continued*)—

lower leaves begin to roll and take on the harsh leathery appearance characteristic of this disease; this is " secondary " Leaf Roll. In the experimental glasshouse, and probably out of doors also in hot seasons, the primary condition passes rapidly into the secondary, and in some varieties the former may be hardly noticeable (P. A. Murphy and R. M'Kay, *Sc.Proc. Roy. Dubl. Soc.*, xvii., xviii., xix.).

The foregoing are the most important potato viruses, but there are many others about which little is known, and which may or may not be mixed infections. Such are "aucuba" Mosaic, in which the leaves of affected plants develop bright yellow spots. In this connexion it should be mentioned that potatoes often develop yellow patches on the leaves which closely resemble aucuba Mosaic; this condition does not appear to be a virus disease, but may be a particular physiological state possibly due to frost. Other potato virus diseases include Rolled Edge, Leaf-rolling Mosaic, Spindle Tuber, etc. Mention must be made of a common condition known as Curly Dwarf, where the potato plant is only a few inches high and of a rosetted appearance. This has recently been shown to be due to a crinkle virus (R. N. Salaman, *Proc. Roy. Soc.*, B, 1930).

Infectious Nature of Potato Viruses and Some Methods of Transmission—The infectious nature of plant viruses in general has already been referred to, and this is true also of potato viruses. Healthy potato plants can be infected with a virus in several ways. One method is by means of the needle used in the following manner: a drop of sap from an infected plant is placed on a leaf of a healthy plant, and a number of scratches are made through this drop with a sterile needle; for some reason the inoculation is made more effective if the drop of sap containing the virus is rubbed over the leaf sufficiently hard to cause abrasion of the leaf surface.

This " leaf-mutilation " method of inoculation is applicable chiefly to the mosaic group of potato viruses, which includes Crinkle and Streak. Another method of transmission is by grafting, where a scion of a diseased plant is grafted on to a healthy one. All potato viruses are transmissible by this method; Leaf Roll, which cannot be inoculated into a healthy plant by the needle, is transmissible by grafting.

It will be realized that both these methods—inoculation and grafting—are artificial, and that it cannot be by either of these means that the viruses are spread in nature. There is, therefore, a third method, and that the most important, as it is the means by which infection is carried from plant to plant in the field. This transmission is brought about by the agency of one or more of the insects which infest the potato plants and are the vectors of the virus diseases. Mention only is made here of insect vectors, as they are dealt with more fully in the succeeding paragraph. One of the characteristics of plant viruses was shown to lie in the systemic nature of the disease, *i.e.*, the infective principle was to be found in all parts of the plant. As would be expected, therefore, the virus is to be found in the tuber, and by this means the disease is propagated, from year to year. Not

POTATO (*Continued*)—
only is the virus disease thus propagated, but it is also spread about the country in the "seed" tubers. It is unfortunate that there is no means of differentiating, except in a few instances, a virus-infected tuber from a healthy one, and it often happens that tubers from a diseased plant are deliberately selected because of their small size and apparent suitability for "seed." Occasionally at the time of harvesting a plant the parent sett may be found unrotted amongst the new tubers; such an unrotted sett is of a characteristic woody and indurated appearance with glassy interior. This failure of the parent sett to rot was for long associated with the virus of Leaf Roll, but such a view has now been found to be erroneous, the unrotted sett often occurring in healthy plants.

Dissemination of Potato Virus Diseases in the Field—A very important aspect of plant virus diseases in general and of potato viruses in particular is their close association with insects. From the practical point of view, the spread of potato virus diseases, apart from the sale of infected "seed" potatoes, is largely governed by the presence or absence of the insect vector. It will be well, therefore, briefly to examine the insect fauna of the potato in their relationship to potato viruses. Insects, broadly speaking, can be divided into two main groups according to their method of feeding: firstly, those which eat the leaf-substance and are known as biting insects—such are caterpillars or beetles; and, secondly, those which have no jaws in the accepted sense, but suck the plant sap by means of a hollow, needle-like proboscis, which is inserted into the plant tissue. Examples of the latter class are the well-known green fly or aphides, capsid bugs, etc. The evidence that biting insects are concerned with the transmission of potato viruses is inconclusive, and they will not be dealt with here. There remains, then, this large group of sucking insects, or *Hemiptera*; examples of this class are the *Aphididæ* or green flies, *Capsidæ* or capsid bugs, and *Jassidæ* or leaf hoppers.

Study of the relationship of insects and plant viruses reveals the interesting fact that sometimes an association exists between a plant virus and one particular insect which alone can disseminate it. Experiments (K. M. Smith, *Ann. Appl. Biol.*, xvi. 2, 1929) with the insect fauna of the potato have shown that a similar state of affairs exists in the case of potato virus diseases, especially Leaf Roll, and that there is one particular insect which appears to possess an affinity for potato viruses; this does not necessarily mean, however, that other insects cannot transmit potato virus diseases. The insect in question is a species of aphis or green fly known as *Myzus persicæ* Sulz., and it is a small green insect similar to, but smaller than, the aphis which occurs commonly on rose trees. The other sucking insects found attacking potatoes, such as the green capsid bugs, the black and yellow or green leaf hoppers, and the other species of aphis, have all failed to transmit potato viruses, and there is little doubt that the aphis, *M. persicæ*, is the transmitting agent in nature. It may be well to remark here that the capsid bugs do produce an injury to the potato plant when feeding, in which the shoots are often killed and the leaves covered with brown

POTATO (*Continued*)—

spots, which later may fall out, giving a "shot-hole" effect. This condition, known as "stung" in some parts of the country, is due to a toxin contained in the salivary secretions of the insect, and has no connection with virus diseases.

What, then, is the mechanism by which the insect infects a healthy potato plant with a virus? To understand this, the mouthparts of the aphis must be briefly explained. The proboscis or beak of the insect consists of two pairs of grooved needle-like stylets which fit into and slide within the proboscis proper. The close apposition of the needle-like stylets forms two channels, down one of which flows the insect's saliva, while up the other flows a mixture of sap and saliva drawn upwards by the action of the pharyngeal pump situated in the head of the insect. The mechanism of infection is thus made clear: by feeding upon a virus-diseased plant, the saliva of the aphis becomes contaminated with the infective principle; and when the insect feeds upon a healthy potato plant the contaminated saliva is injected into the plant and the virus disease thus established. So far as the mosaic group of viruses are concerned, where transmission is effected by means of needle inoculation, this procedure is clear enough. It is not, however, quite so straightforward in the case of the virus of Leaf Roll, which cannot be inoculated by the needle, but which is very easily transmitted by *M. persicæ*. An explanation of this may lie in a possible obligate connection between the virus and its insect vector. It may be that the virus undergoes some slight modification within the body of the aphis which attunes it to reception by the plant. Recent work by the writer upon the Leaf Roll virus and the aphis *M. persicæ* has revealed some points of interest in this connection.* An infective aphis is able to transmit Leaf Roll after two hours' feeding upon a healthy potato plant, while, conversely, an uninfective aphis can become infective after six hours' feeding upon a leaf-rolled potato plant. It is not possible, however, for a non-infective aphis to pick up the virus and infect a healthy potato plant in a total of eight hours; a minimum period of about fifty-four hours seems necessary for the carrying out of the whole process. This may indicate that some change in the virus takes place within the body of the aphis necessitating an incubation period of some fifty-four hours, or it may be merely the time occupied by the passage of the virus round the body of the aphis from the time it is swallowed with the sap to the time it re-enters the salivary juices.

In addition to the infection of healthy potato plants in the field by the migration from plant to plant of virus-carrying aphides, there is another possible opportunity for infection which must not be overlooked. This opportunity occurs when the "seed" tubers are in the sprouting trays. *M. persicæ,* as well as being a plant-feeding aphis, is also *par excellence* a sprout-infesting insect. By feeding virus-carrying aphides upon healthy sprouted tubers in February, the writer has produced, two months later, a crop of badly "rolled" plants which were useless for tuber production. This experimnet

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* *Ann. Appd. Biol.*, xviii., No. 2, 1931.

POTATO (*Continued*)—

was performed under glasshouse conditions, but the same would have been true if the tubers had been grown out of doors, though the results would have been delayed. The rapidly growing shoots of a potato tuber are ideal for the introduction of a virus, and it will readily be seen how infection could be spread through the "seed" by the breeding of large numbers of aphides and their subsequent migration from tuber to tuber. It is thus quite possible for a supply of "seed" tubers which were in the main healthy when put into a store, to give rise to a crop showing a high percentage of virus-infected plants.

Should the reader wish for a description of the aphis *M. persicæ*, he is referred to "The Plant Lice or Aphidæ of Great Britain," vol. i., p. 318, 1926, by F. V. Theobald, where a full account of the insect is given.

Plant "Carriers" of Potato Viruses and Sources of Infection in Nature—In carrying out studies upon potato virus diseases, the investigator has to reckon with the peculiar and perplexing phenomenon known as "carrying." A "carrier" plant is one which, although outwardly healthy and normal in every way, yet contains in its sap one or more viruses which are highly infectious to other non-carrying or susceptible plants. This phenomenon is known to occur in the case of certain virus diseases of the hop (see Hops), but is of most frequent occurrence in the potato plant, and thereby presents a very serious difficulty to the investigator, who must first be sure that his experimental potato plants are free of hidden viruses before any experiments can be performed. The potato viruses most frequently carried in this way are those belonging to the mosaic group, particularly Crinkle and Streak; so far no authentic case is known of the "carrying" of the Leaf Roll virus. If a scion, then, from such a virus-carrying plant be grafted on to a healthy susceptible plant of another variety, the disease develops in the susceptible stock, while the scion continues to show no symptoms.

There are, of course, parallel cases of "carrying" in certain diseases of man; typhoid, for example, though of microbic origin, is frequently carried by a person who, himself healthy, is yet capable of infecting other susceptible persons with the disease. It is important to differentiate between a plant carrier and an immune plant; in the former case, as has been already explained, the infection is present in the plant which shows no symptoms, but is nevertheless infectious to other plants, while in the latter the infective agent is unable to gain an entrance to, or multiply within, the plant; in the case of wart-resistant varieties of potato, for example, the wart organism is unable to enter such resistant plants, or if it enters is unable to thrive. So far, no potato variety immune to virus diseases has been discovered, although there exists a very wide difference in varietal reaction and susceptibility to the various virus diseases.

Because a potato variety is a carrier of one virus, it does not follow that such a variety cannot be infected with other viruses; Up-to-Date, for example, is a well-known carrier of Streak, but this variety can quite easily be infected with, and show symptoms of, Leaf Roll.

In the present state of knowledge it is not possible to say exactly

POTATO (*Continued*)—

how far the insect vector is capable of infecting susceptible potatoes from a "carrying" variety, although it is highly probable that infection is so transmitted. Further research may show that it is very unwise to grow certain varieties of potatoes in close proximity, for the reason that one variety is a carrier, and so a potential source of infection for the other which is susceptible. Salaman (*Proc. Roy. Soc.*, B, 1930) has shown that "King Edward" is a very frequent carrier of a severe form of Crinkle, and that the ordinary commercial stocks of King Edward are heavily infected. "Arran Victory," on the other hand, is very susceptible to this same Crinkle, and in this variety it appears as a virulent and often fatal disease. Transmission of the virus from the symptomless and apparently healthy King Edward to the susceptible Arran Victory can easily be effected by artificial method, but transmission by the aphis *M. persicæ* has yet to be accomplished. If this is proved possible, then it will be obvious that King Edward and Arran Victory should not be grown in the same field.

Recent work at Cambridge has revealed the existence in nature of a hitherto unsuspected reservoir of infection for potatoes. Firstly, it has been discovered that the common solanaceous weed, Black Nightshade (*Solanum nigrum*), is a symptomless carrier of one or more potato viruses, and, secondly, it has been found very easy to infect certain potato varieties with these viruses by means of the aphis *M. persicæ* from such a "carrying" weed. The practical importance of this discovery depends to a certain extent on the retention of the virus by the *S. nigrum* till the following year. The weed must itself first be infected with the virus by means of *M. persicæ* from a diseased potato plant before it can act as a carrier. Although the occurrence of virus-carrying weeds in the midst of a potato crop already infected is important, it is obviously more important if a fresh crop of possibly virus-free potatoes were to be planted the following year close to numbers of virus-carrying weeds. The retention of the virus by *S. nigrum* from the year of infection till the following year would be effected by the fulfilment of either of the two following conditions: firstly, if the weed acts as a biennial; and, secondly, by the propagation of the virus through the seed. It is fairly certain that *S. nigrum* can act as a biennial, and it also seems possible for pieces of root stock left in the ground over winter to give rise to fresh plants the following year; in the latter case, these plants also would contain the virus, because, owing to the systemic nature of virus infection, the root stocks would contain the virus. The passage of the virus through the seed is less likely, as plant viruses are seldom transmitted in this manner; this point, however, is in process of being tested. Research is now being carried on at Cambridge to test the virus-carrying powers of other perennial solanaceous weeds, such as *S. dulcamara*, Bittersweet, etc. The possibility that other common weeds outside the Solanaceæ may act as carriers is also being investigated.

Economic Importance—Virus diseases of the potato have existed since very early times, although their true nature was not recognized.

POTATO (*Continued*)—

It has long been known that if potatoes were grown in the same locality from their own "seed" year after year, they gradually degenerated and had to be replaced by fresh "seed" from another locality. This degeneration was formerly considered to be due to long-continued propagation from the same stock, but it is now recognized, however, that the real reason for such deterioration lay in the gradual contamination of the entire crop with one or more virus diseases, which were perpetuated from year to year in the "seed." There is probably no reason why potatoes should not be grown indefinitely from their own tubers, provided the virus factor could be eliminated.

It has been said that 90 per cent. of the potato stocks of this country are infected with Mosaic disease, and this is no exaggeration. In addition, a large percentage of certain well-known varieties, such as "King Edward," which carry viruses are also infected. Although this fact does not reduce the yield of the "carrying" variety, it becomes nevertheless a potential source of infection to other susceptible varieties growing near-by. The general idea of the superiority of Scotch "seed" potatoes over English "seed" has long been held, and is largely due to the comparatively small percentage of virus infection. Such freedom from virus is thought to be due to a great extent to a scarcity of the insect vector of potato viruses, *i.e.*, the aphis *M. persicæ*, in Scotland. In this connexion an interesting and important piece of work would be a census of the aphis population of the potato plants in the Scotch potato districts, carried out over a period of years, in order to ascertain the degree of infestation by this insect and attempt to correlate its incidence with that of virus disease. There is little doubt of the economic importance of virus diseases to the potato-growing industry. Mosaic disease, the most widespread of potato viruses, undoubtedly reduces the yield to a certain extent, though the reduction is never as great as that produced by the virus of Leaf Roll.

The writer is indebted to Mr. John Orr, of the Department of Agricultural Economics, Manchester University, for the following figures illustrating the reduction in yield and monetary loss due to potato Leaf Roll. The experiments from which the figures were obtained were carried out over three years at seventeen centres in Lancashire and Cheshire. Yields from over 1,200 plants were weighed; the yields from plants affected with Leaf Roll compared with the yields from apparently healthy plants from the same "seed" showed a reduction of 61·5 per cent. The reductions ranged from 0·83 cwt. per acre to 21 cwts. per acre, the latter result coming from thrice-grown "seed" which had been used without any scrutiny or selection when growing. The financial losses at the prices ruling varied from 9s. 5d. to £5 15s. 0d. per acre.

Methods of Combating Potato Virus Diseases—The question of the control of potato viruses may be approached from four possible standpoints. There is, firstly, the elimination of the aphis vector;

POTATO (*Continued*)—

secondly, the breeding of a potato variety immune to virus diseases; thirdly, the destruction by "roguing" of infected plants in the field; and, fourthly, the deliberate production of stocks of known virus-free tubers under insect-proof conditions.

The elimination of *M. persicæ*, the chief insect vector of potato viruses, offers considerable difficulty. This aphis is exceedingly widespread and almost omnivorous in its feeding habits; it has been recorded from over fifty different plant species. Where routine spraying for potato blight is carried out, it might probably be worth while to incorporate an aphicide in the spray. Mention has been made of the risk of infection being carried by *M. persicæ* to "seed" tubers in the sprouting trays. Much can be done in this case to minimize the risk of infection by regular twice-a-week fumigation of the shed or store containing the trays. The best fumigant to use is pure nicotine; a little should be poured into a metal saucer and vaporized on a tripod over a spirit lamp.

As regards the breeding of a virus-immune potato, the prospects are not very encouraging. When it is considered that potato viruses will attack other members of the Solanaceæ—tobacco, for example—the difficulty of breeding an immune variety within a susceptible species seems great. Probably, however, the way will be clearer when further knowledge as to the nature of viruses is obtained. There is no doubt that the production of such a virus-immune variety would go a long way to solve the potato virus problem. "Roguing," or the elimination of virus-infected potatoes in the field, is only practicable in the case of a disease like Leaf Roll, where the symptoms are definite and easily recognizable, and where the complications of masking of symptoms and plant carriers are less likely to occur.

The last method, that of raising virus-free stocks of potatoes, seems to offer a practical solution, and such stocks are being built up at the Virus Disease Research Station at Cambridge at the present time. Beginning with a nucleus of tested virus-free tubers, these are multiplied by various methods of propagation in the insect-proof glasshouse, and parcels are then grown in carefully selected localities, such as high altitudes and stretches of moorland, where the occurrence of virus-carrying aphides is unlikely. It is hoped that these stocks will in time be not only sufficiently large to replace the existing virus-infected potatoes, but will also produce yields comparable to those obtainable from the best Scotch "seed." K. M. S.

POTASSIUM (Symbol K; atomic weight 39·096; atomic number 19)—A soft white metal violently acted upon by water, with ignition of the hydrogen gas liberated. Of great importance in agriculture, since its presence in the soil is essential to proper health of vegetation, and in the animal body its ions have a regulating effect upon the cardiac rhythm. The chief sources are sylvine (KCl), carnallite (KCl, $MgCl_2$, CH_2O), and kainite (K_2SO_4, $MgSO_4$, $MgCl_26H_2O$)—the latter is used directly as a potash manure. The iodide and citrate are used in medicine, the latter as a remote alkali. (See Acid; Fertilizers; Manuring, Principles of.)

POULTRY—FOWLS—Fowls have been kept in domestication for many centuries and in all lands, both for their economic qualities and for breeding fighting cocks for sport.

Distributed throughout the different countries of the world are numerous breeds and varieties of fowls, many of which are seldom seen outside their native country.

In the British Isles some forty to fifty breeds of fowls are recognized by the Poultry Club, and their various breed and varietal characteristics are described in the "Book of Standards" issued by the Club (published by the Secretary, The Poultry Club, 3, Ludgate Broadway, London, E.C. 4). Varietal differences within the breed are those of plumage colour and shape of comb.

Poultry keeping attained great popularity in the British Isles about 1880; the making of new breeds and the improvement of breed characteristics has received great attention from the breeder of stock for exhibition, and much benefit has followed the careful selection of breeding birds on the basis of breed characteristics.

In the more recent years, and aided by the introduction of the trap nest, selection for high egg-production has resulted in a great improvement in this direction, and nowadays it is not uncommon to hear of flock averages of 180 eggs, and occasionally individual outputs of 300 eggs per annum.

As eggs are by far the most important product in the poultry industry of the British Isles, those breeds particularly adapted to egg-production, and yet not difficult to breed true to their external varietal characteristics, were always kept in the greatest numbers, and their improvement from the egg production standpoint has therefore been more rapid.

Classification—Unlike the cattle of the British Isles, a number of the popular and economically important breeds of fowls are of relatively recent origin, and are derived in many cases from foreign sources.

Fowls may be classified in one of several ways, viz.:

1. According to the country of their origin.

2. According to their weight, into "Light Breeds" and "Heavy Breeds," a somewhat ambiguous classification, but frequently used in poultry shows.

3. According to their economic qualities into—

(i.) Egg-Laying Breeds, which includes breeds which are good egg-layers but exhibit poor table qualities.

(ii.) Dual Purpose Breeds, which are good egg-layers and possess fair table qualities.

(iii.) Table Breeds, which excel in table qualities but are poor egg-layers.

(iv.) Fancy Breeds—that is, breeds of fowls usually kept for their splendour of plumage.

4. According to the propensities shown by the breed to become broody, into Non-sitting Breeds and Sitting Breeds, and in the classification which follows this method of arrangement has been adopted. In each class the breeds have been arranged in order of their popularity.

POULTRY (*Continued*)—

(*a*) *Non-sitting Breeds*—This class includes breeds in which only a small percentage of birds ever show an inclination to become broody. The breeds are good layers, and most of them produce a white-shelled egg. By reason of their small size and poor quality of flesh, they are, with few exceptions, inferior for table use.

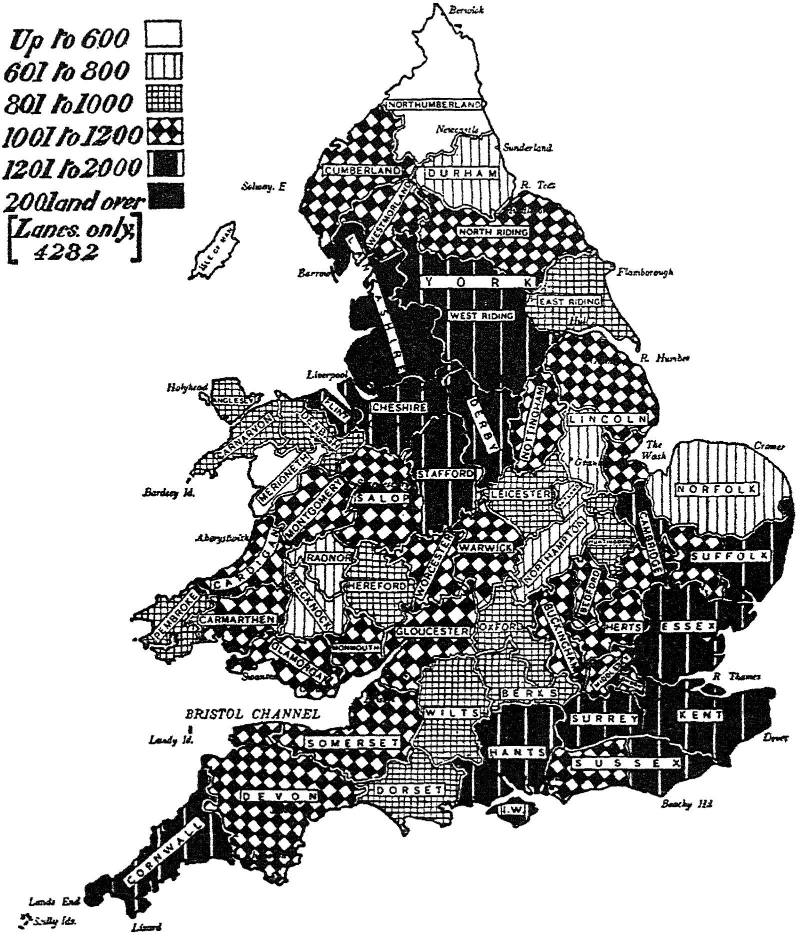

Fig. 18.—Showing the Number of Fowls per 1,000 Acres of Crops and Grass in 1924.

(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

(*b*) *Sitting Breeds*—This class includes breeds in which there is a natural inclination to become broody; they are larger and less nervous in temperament than breeds in the non-sitting class.

POULTRY (*Continued*)— CLASSIFICATION OF

	Breed.	Country of Origin.	Type of Comb.	Colour of Legs.	Colour of Skin.	Colour of Egg Shell.	Approximate Weight of Adult Bird.	
							Male.	*Female.*
							Lbs.	*Lbs.*
Non-sitting Breeds.	**Leghorn**	Italy	Single	Yellow	Yellow	White	6	4
	Ancona	Italy	Single or rose	Yellow mottled with black	Yellow	White	6-7	5-6
	Bresse	France	Single	Dark blue	White	White	6	5
	Welsummer	Holland	Single	Yellow	Yellow	Brown	6	5
	Minorca	Spain	Single	Black or dark slate in Black variety; pinkish-white in White variety	White	White	6-8	5-7
	Campine	Belgium	Single or rose	Leaden-blue	Greyish-white	White	6	5
	Coveney White	Britain	Cup-shaped	Yellow	Yellow	White	4½-5½	3½-4½
	Scots Grey	Britain	Single	White mottled with black	White	White	7	5
	Redcap	Britain	Rose	Slate	Greyish-white	White	6	5
	Old English Pheasant Fowl	Britain	Rose	Slate-blue	Greyish-white	White	6-7	5-6
	Hamburg	Britain	Rose	Leaden-blue	Greyish-white	White	5	4
	Andalusian	Spain	Single	Dark slate	Grey	White	7-8	5-6
	Polish	Poland	Horn	Dark blue	Grey	White	6	5
	Spanish	Spain	Single	Pale slate	Greyish-white	White	7	6
	Sicilian Buttercup	Italy	Cup-shaped	Willow green	White	White	6	5

BREEDS OF FOWLS

Varieties.	*Remarks.*
White, Black, Brown, Exchequer, Cuckoo, Buff, Blue, Silver Duckwing, Gold Duckwing	This breed is very hardy and suited to all soils and situations. The *White Leghorn* is the most popular variety; it is an excellent egg-producer, and is amongst the most widely kept of all breeds of fowls. The *Black Leghorn* is an excellent egg-producer, but it has never attained the popularity of the White variety, possibly on account of its more nervous temperament. The *Brown Leghorn* is a bird of delightful plumage colour and deserving of greater popularity than it has obtained in the past. Such high egg production is not generally obtained in this variety as in the White Leghorn, and much improvement can be obtained by selective breeding. Males of this variety, which belongs to the "Gold" class of fowls, are now a good deal in demand for sex-linked breeding. The *Exchequer Leghorn* is another variety which enjoys considerable popularity.
One only. Plumage colour beetle-green with white tippings to the feathers	This breed is hardy and suited to all soils and situations. It is an excellent layer. Being very active and strong fliers, it is difficult to confine birds of this breed within wire-netted runs; they are consequently best suited to free range.
White, Black	Hardy and suited to most soils and situations. Is a good egg-producer, and although only of medium size the Bresse is one of the very best table birds, the breast being well developed and the quality of the flesh excellent. Both varieties are popular, but the White is probably more extensively kept.
One only	Recently introduced to Britain, and gaining in popularity.
Black, White	Suited to well-drained soils and less exposed situations. Renowned as a layer of large eggs.
Silver, Gold	Suited to well-drained soils and less exposed situations.
One only	A relatively new breed produced by crossing White Leghorns and Sicilian Buttercup.
One only	Relatively few of this breed are to be found.
One only	Hardy and suited to well-drained but exposed situations. The comb of this breed is exceptionally large.
Gold, Silver	Hardy, but not a popular breed.
Black, Silver Spangled, Gold Spangled, Silver Pencilled, Gold Pencilled	Suited to dry and mild situations. Egg small, and this, combined with its nervous temperament, renders it of little economic importance.
One only	Suited to well-drained soils and less exposed situations.
One only	Suited to mild situations; a handsome breed, but of little economic value.
One only	Suited to mild situations only, and not recommended for its economic qualities.
One only	Hardy.

POULTRY (*Continued*)— CLASSIFICATION OF

	Breed.	*Country of Origin.*	*Type of Comb.*	*Colour of Legs.*	*Colour of Skin.*	*Colour of Egg Shell.*	*Approximate Weight of Adult Bird.*	
							Male.	*Female.*
							Lbs.	*Lbs.*
Sitting Breeds.	**Wyandotte**	America	Rose	Yellow	Cream	Tinted	8	6
	Rhode Island Red	America	Single or rose	Yellow or red horn	Yellow	Brown	8	6
	Sussex	Britain	Single	White	White	Tinted	9	7
	Plymouth Rock	America	Single	Yellow	Yellow	Tinted	9	8
	Barnevelder	Holland	Single	Yellow	Yellow	Dark Brown	8	6
	Orpington	Britain	Single	Various, according to variety	White	Tinted and brown	9	7
	Indian Game	Britain	Pea	Yellow	Yellow	Brown	8	6

BREEDS OF FOWLS—*Continued*

Varieties.	*Remarks.*
White, Columbian, Black, Buff, Blue, Buff Laced, Blue Laced, Gold Laced, Silver Laced, Partridge, Silver Pencilled	Hardy and suited to all soils and situations. The White Wyandotte is the popular variety; it is an excellent egg producer and a good winter layer. The *White Wyandotte* shares with the White Leghorn the reputation of being the most widely kept of any breed and the facility with which it can be satisfactorily kept on free range or intensively. The cockerels grow rapidly and fatten well; in a well-finished chicken the skin is light-cream in colour.
Single Comb, Rose Comb	Hardy and suited to all soils and situations. Excellent layers of a brown-shelled egg. Produce table birds of good size, but not of the highest quality.
Light, Red, Brown, Speckled, Buff	Most suited to well-drained soils. The Sussex is one of the very best table breeds, being large with white skin and legs. The *Light Sussex* is the most popular variety and is a splendid all-round breed, combining good egg-laying capacity with the most excellent table qualities.
Buff, Barred, White, Black	Hardy and suited to most soils and situations. The *Buff Plymouth Rock* is the most popular variety. They are good layers, and produce table birds of good size and fair quality, finishing with a good appearance. This variety is gaining in popularity. The *Barred Plymouth Rock* obtained considerable popularity in Britain as an exhibition breed in the eighties and nineties, but has since declined in popularity until its numbers are relatively few. In Canada and the United States of America, however, the Barred Plymouth Rock is a popular breed, and in those countries has been subjected to selective breeding for egg-production.
Laced, Partridge, Black	Hardy and suited to most soils and situations. Renowned for size and dark brown colour of eggs, which are produced in fair numbers by selected strains.
Buff, Black, White, Blue, Cuckoo, Spangled, Jubilee	Best suited for well-drained soils and less-exposed situations. An excellent table bird. The *Buff Orpington*, having white flesh and legs and also being a fair egg-producer, is the best all-round variety of the Orpingtons. The *Black Orpington* imported into Australia underwent much selection for egg-production. High egg-producing strains were reimported into this country under the name of "Australian Black Orpingtons" or "Australorps."
One only	Best suited to well-drained soils and less-exposed situations. Frequently called Cornish Game. A poor egg-producer, but a good table bird on account of the large amount of breast meat; is somewhat heavy in bone and the flesh is not of the first quality. Males of this variety are excellent for crossing with females of Sussex for producing table birds, the progeny inheriting the white skin and legs and fine quality flesh of the Sussex, combined with the width of breast and quantity of breast meat of the Indian Game.

POULTRY (*Continued*)— CLASSIFICATION OF

	Breed.	*Country of Origin.*	*Type of Comb.*	*Colour of Legs.*	*Colour of Skin.*	*Colour of Egg Shell.*	*Approximate Weight of Adult Bird.*	
							Male.	*Female.*
Sitting Breeds.	**Dorking**	Britain	Single	White	White	White	*Lbs.* 12-14	*Lbs.* 9-10
	Old English Game	Britain	Single	Various, according to variety	White	Tinted	7-9	5-7
	Houdan	France	Leaf	White mottled with black	Cream	Tinted	6	5
	Langshan	China	Single	Blue-black; soles of feet pink-white	Grey	Brown	9	7
	Faverolle	France	Single	Various, according to variety	White	Cream	8-10	6½-8½
	Silkie	E. Asia	Cushion	Lead-blue	Bluish-grey	Cream	3	2
	Cochin	China	Single	Yellow, except in Black variety, when lizard	Yellow	Brown	10-13	9-11
	Brahma	India	Pea	Yellow	Yellow	Brown	10-12	7-9
	Aseel	India	Pea	No fixed colour	Cream	Tinted	6	5
	Orloff	Russia	Raspberry	Yellow	Yellow	Brown	8	6
	Sumatra Game	India	Pea	Dark olive or black	White	White	5	4
	Crève-Cœur	France	Horned	Black or Slate blue	White	White	9	7
	Malines	Belgium	Single	Pink-white	Cream	Tinted	9	7
	Scots Dumpie	Britain	Single or rose	White, except in Black variety	White	White	7	6
	Malay	S. Asia	Walnut	Yellow	Yellow	Brown	11	9
	Yokohama	Japan	Single or pea	Various	—	—	4-6	2½-4

BREEDS OF FOWLS—*Continued*

Varieties.	*Remarks.*
Dark, Silver Grey, Red, White, Cuckoo The *White* variety has a Rose comb.	Suited to well-drained soils and not exposed situations. A poor egg-producer, but an excellent table bird on account of its large size and the fine quality of its flesh combined with a white skin and legs.
Black-breasted Red, Black, Bright Red, Blue, Blue-Red, Brown-Red, Crele, Duckwing, Pile, Spangled, White, and other varieties	Hardy and suited to dry, exposed situations. Very fine table qualities, but poor egg-layers.
One only	Hardy, good egg-layers and table birds, and of value for crossing.
One only	Suited to dry and less-exposed situations.
Salmon, Buff, White, Blue	Hardy. Good egg-layers and table birds. Enjoy much popularity in their native country.
White, Black, Blue	Frequently used as sitting hens owing to broody propensities.
Buff, Black, White, Partridge, Cuckoo	Suited to dry, mild situations. Not of economic importance. The Cochin was imported into Britain about 1847 and with the Brahma attained great popularity as an exhibition breed.
Light, Dark	Suited to dry, mild situations. Not of economic importance.
Black, Grey, Red, and other varieties	Not of economic importance.
Mahogany, Black, Spangled, White	Very hardy. Poor egg-layers. Not of economic importance.
One only	Hardy. Not of economic importance.
One only. Lustrous green-black	Suited to dry, mild situations. A fair egg layer and good table bird.
Cuckoo, Blue	Hardy. Moderate egg layers; good table qualities.
Cuckoo, Black, Silver-Grey	Hardy, good layers and table birds.
Spangled, Black-Red, etc.	Not of economic importance.
Spangled, Black-Red, Blue-Red, Red Saddle, White	Suited to dry, mild situations. Not of economic importance.

POULTRY (*Continued*)—

Several of the sitting breeds excel as egg-producers, while others excel as table birds.

In some breeds in the class, selective breeding for high egg production has resulted in a partial or a total elimination of the broody characteristic in certain individuals.

The following table indicates the general merits as Table Birds and Table Egg Producers of the various breeds:

Class.	*Table Qualities.*	*Egg-Laying Qualities.*	*Breeds.*
Non-sitting Breeds	Good	Superior	**White Bresse.**
		—	—
	Less good	Good	**Minorca, Campine, Redcap, Black Bresse, Sicilian Buttercup.**
		Less good	**Scots Grey, Andalusian, Old English, Pheasant Fowl, Polish, Spanish.**
	Inferior	Good	**Hamburg, Coveney White.**
		Superior	**Leghorn, Ancona.**
Sitting Breeds	Superior	Good	**Light Sussex, Houdan.**
		Less good	**Sussex, Orpington, Faverolle.**
		Inferior	**Dorking, Old English Game.**
	Good	Superior	**Wyandotte, Rhode Island Red.**
		Good	**Buff Plymouth Rock, Barnevelder.**
		Less good	**Plymouth Rock, Langshan, Crève-Cœur, Malines, Scots Dumpie.**
		Inferior	**Indian Game, Aseel, Brahma, Cochin, Malay, Orloff.**

DUCKS—The domesticated breeds of duck, with the exception of the Muscovy, have originated from the wild duck (*Anas boschas*), the various breeds and varieties being the result of selective breeding.

Originally ducks were kept chiefly on account of their flesh, but in recent years very prolific laying breeds have resulted from selective breeding for high egg production. This, combined with a steady market demand for duck eggs, has encouraged the keeping of egg-laying breeds of duck.

Swimming water is necessary if the heavy table breeds of duck are to be successfully kept, but this is not necessary when keeping egg-laying breeds; they thrive well without swimming water, and forage extensively over the land if allowed free range.

Amongst the high egg-laying breeds the breeders' object is to obtain and maintain flocks which produce only white-shelled eggs, these being in greatest commercial demand; consequently, birds laying greenish-shelled eggs should never be used for breeding.

The following is a list with the main characteristics of the most important breeds of ducks:

POULTRY (*Continued*)—

Breed.	*Country of Origin.*	*Colour of Legs.*	*Colour of Skin.*	*Colour of Egg Shell.*	*Approximate Weight of Adult.*		*Table Qualities.*	*Egg-Laying Qualities.*
					Male.	*Female.*		
Indian Runner	East Indies	Orange	Yellow	White	*Lbs.* 3½-5	*Lbs.* 3-4½	Inferior	Superior
Khaki Campbell	Britain	Dark orange	Yellow	White	—	—	Poor	Superior
Orpington	Britain	Orange-yellow	Cream	White	7	6	Fair	Good
Magpie	Britain	Orange	Cream	White	5½-7	4½-6	Fair	Good
Penguin	East Indies	Dark tan	Greyish-white	White	7-9	7-8	Fair	Fair
Cayuga	America	Orange-brown	Yellow	Green	8	7	Good	Fair
Pekin	China	Bright orange	Yellow	White	9	8	Good	Good
Aylesbury	Britain	Bright orange	White	White or greenish-white	10	9	Superior	Moderate
Rouen	France	Red-brown	Yellow	Greenish-white	10	9	Good	Poor
Muscovy	South America	Orange	Yellow	White	8-10	6-7	Poor	Poor

Breed.	*Varieties.*	*Remarks.*
Indian Runner	*White, Fawn and White, Fawn*	Hardy. Popular egg-laying breed. Are excellent foragers and do not require swimming water. This breed is peculiar in its very upright carriage.
Khaki Campbell	One only	Hardy. Popular egg-laying breed. Are good foragers and do not require swimming water.
Orpington	*Blue, Buff*	Hardy. Are egg layers and produce a good though not large table bird. Swimming water, though not essential, is an advantage.
Magpie	*Black and White, Blue and White*	Hardy. A handsome breed of black and white colouring.
Penguin	One only	
Cayuga	One only	Hardy. Produce good table birds.
Pekin	One only	Smaller in size and of more upright carriage than the Aylesbury. They are hardy and the best layers amongst the birds of good table qualities.
Aylesbury	One only	Only moderate egg layers, but produce the largest and most excellent table birds. For good results with this breed swimming water is necessary.
Rouen	One only	Of direct descent from the Mallard, which they resemble closely in plumage colour. Produce good table birds of fine quality flesh. For good results swimming water is necessary.
Muscovy	*Black and White, White.*	Found in the wild state in South America.

POULTRY (*Continued*)—

GEESE—The domestic breeds of geese, with the exception of the Canadian and the Egyptian geese, have the wild Greylag goose (*Anser anser*) as their ancestor. Geese require free range over pasture or waste land, and are therefore most suited for inclusion in the poultry stock of the general farm. They should, however, be kept separate and away from other poultry. They are excellent foragers, and on good quality grass require little food other than that which they obtain while grazing.

The main market demand for geese is at Michaelmas and Christmas. They may be got into fat condition by feeding well on fattening foods such as barley, wheat, oats, for some three to five weeks before killing. Those for the Michaelmas market require little else than the grain they obtain on stubbles.

The Embden and Toulouse are the breeds kept most extensively in Britain. Of more recent introduction and rapidly gaining in popularity are the Roman and Chinese geese, which are smaller but much better layers than the two first-mentioned breeds.

Geese commence to lay about the end of February, and will lay from ten to twenty-five eggs before becoming broody; a second batch of eggs may be produced after the first are hatched and the young partly grown.

One gander is usually mated to two to four geese, and these will breed for six to ten years.

The following is a list with main characteristics of the most important breeds of geese:

Breed.	*Country of Origin.*	*Colour of Legs.*	*Colour of Skin.*	*Approximate Weight of Adult.*		*Table Qualities.*	*Egg-Laying Qualities.*
				Male.	*Female.*		
				Lbs.	*Lbs.*		
Embden	Germany	Bright orange	Cream	30-34	20-22	Superior	Poor
Toulouse	France	Orange	Yellow	28-30	20-22	Good	Fair
Roman	Italy	Dark orange	Cream	10-14	8-12	Moderate	Good
Chinese	China	Dark orange	Yellow	12-16	10-14	Moderate	Good

	Colour of Plumage.	*Remarks.*
Embden	*White*	The largest and best goose for table purposes. They are hardy and good foragers and sitters.
Toulouse	*Grey*	Somewhat slow growers. They are poor foragers and do not frequently become broody; they are uncertain sitters.
Roman	*White*	Although small, are rapid growers and prolific layers, and on this account are excellent for crossing with Embden or Toulouse. They are hardy and excellent foragers.
Chinese	*Grey, White*	Very hardy. Owing to their excellent laying qualities and rapid growth they are excellent for crossing with Embden or Toulouse.

POULTRY (*Continued*)—

GUINEA FOWL—The domesticated guinea fowl originated from the wild guinea fowl of West Africa (*Numidia meleagris*). Guinea fowl are hardy and live a half-wild life; they are, therefore, only suitable for keeping on the general farm.

Their call, which has a particularly piercing note, their wild nature and disposition to lay in out-of-the-way places, and their pugnacity are reasons for the limited utilization of these birds.

The female lays from forty to eighty eggs per annum; these are small, weighing 1¼ to 1½ ozs. each, but are of good flavour, and can be sold readily.

Guinea fowl flesh has a gamey flavour, and they consequently command a good market as table birds during the close season for game, particularly during February and March. They range in weight from 3 to 5 lbs.

Guinea fowl frequently mate in pairs, but up to six hens may be mated to each male.

If guinea fowl are fed in the evening close to the quarters where it is desired they should roost it is frequently possible to induce them to do so. The provision of secluded nests will result in fewer eggs being laid away and lost.

Their eggs may be hatched under hens in the early part of the season, as the guinea fowl seldom sits until July or August. The period of incubation is twenty-six days.

TURKEYS—The wild turkeys of North America (*Meleagris Mexicana* and *M. gallopavo*) are the origin of the domesticated turkey, of which a number of varieties now exist.

Breed.	*Approximate Weight of Adult.*		*Remarks.*
	Males.	*Females.*	
	Lbs.	Lbs.	
American Bronze	27-36	18-20	The largest and most extensively kept of the domesticated breeds of turkey. The breast is very prominent, the leg bones somewhat coarse, and the quality of the flesh is hardly so fine as that of other breeds.
Cambridge Bronze	18-27	15-20	One of the best breeds for table purposes and for crossing, on account of their fine bone and high quality flesh.
White	22-32	15-22	A breed gaining in popularity; once erroneously believed to be delicate. They produce table birds of large size and fine quality of flesh.
Black or Norfolk ..	18-27	15-20	Having fine quality of flesh and fine bone, this variety makes an excellent cross with the American Bronze for table purposes.
Buff	18-27	15-20	On account of its fine bone and good quality of flesh is excellent for crossing purposes.

POULTRY (*Continued*)—

Turkeys thrive best on well-drained soils and in less exposed situations; they are quite unsuited to heavy, damp land and exposed situations. For good results they should have free range, and on this account they are specially suited for general farms where they may have freedom on grass land or on stubble.

Turkeys are of value on account of their flesh, the main demand for which exists at Christmas time. There is, however, an increasing market for half-grown birds weighing from 6 lbs. at other times of the year.

The turkey hen usually commences to lay in March, and she will lay two batches of eggs, ranging in number from twenty to thirty in each, if not allowed to sit upon the first batch. One male may be mated to four to ten females. The average weight of early hatched turkeys will be from 15 to 20 lbs., when marketed at Christmas.

On p. 965 is a list, with main characteristics, of the most important breeds of turkeys.

SYSTEMS OF POULTRY KEEPING—Three systems of keeping poultry are practised at the present time; these are—

The Free Range System.
The Semi-intensive System.
The Intensive System.

The following notes give a brief description of these three systems.

The Free Range System—Where this system is adopted the poultry houses are spaced well apart, the distance on no occasion being less than 80 yards. The fowls are allowed unrestricted range over the adjoining ground, and no wirenetting fences are erected to separate one flock from another. This system is particularly suited for adoption by the general farmer who has a considerable area of grass land at his disposal.

When the poultry houses are spaced not less than 80 yards apart, and precautions are taken to accustom the birds to their particular house when first put into it, by erecting a temporary wirenetted fence for the first week of their occupation, they will, with few exceptions, return to this house to roost when later allowed free range.

Under this system the number of birds to allow per acre without displacing any other farm stock is relatively small, and should not exceed fifty to sixty.

The advantages of the free range system are —

1. Small capital outlay, no wirenetted fencing being required.
2. A large area of land is benefited by being used by poultry.
3. The fowls are not congested on the land, and are able, therefore, to secure some proportion of their food from the natural products of the soil and of insect life.

The disadvantages of the free range system are—

1. The attendant has a considerable distance to travel when feeding and carrying out other operations.
2. Great risk of damage by vermin.

POULTRY (*Continued*)—

The Semi-intensive System.—Under this system an area of land is set aside for use by the poultry flock. The poultry houses are spaced in some regular formation, and wirenetting fencing is erected to separate each flock. Frequently each house has alternative wirenetted runs so that one may be used while the other is resting. From 16 to 20 square yards of land should be allowed for each bird, giving a total of 250 to 300 birds per acre.

The advantages of the semi-intensive system are—

1. A large number of birds can be kept per acre of land.
2. The labour in attending to the stock is reduced.

The disadvantages of the semi-intensive system are—

1. Additional capital expenditure necessitated by the erection of wirenetted runs.
2. If care is not exercised the grass is liable to become damaged.

The Intensive System—Under this system the birds are kept entirely within the poultry house. For success with this method it is essential that the birds should not be unduly crowded, and 4 square ft. of floor space should be allowed for each bird in the house. In addition, the front of the house should be so constructed as to admit a fair proportion of light to enter the house directly and without its passing through ordinary window glass. There should be not less than 12 square ft. of open front for every 100 square ft. of floor space in the house.

It is only since 1924 that the intensive system has been practised to any extent in the British Isles. It received trial, however, before the date mentioned, but failure in most cases resulted through lack of use of the open front to the house.

Recent knowledge has demonstrated the value of the ultra-violet rays of light for the normal physiological functioning of the body in the absence of a special vitamin D supplement to the ration. These rays are cut off by ordinary window glass.

Experiment has shown, however, that where birds are kept intensively behind ordinary window glass, and, therefore, deprived of the ultra-violet rays of light, the addition of special vitamin D supplement to the ration in the form of cod-liver oil will maintain them in good health and production. (See Reports of Experiments at the National Institute of Poultry Husbandry, Newport, Salop: (1) "Influence of Confinement on the Production of White Leghorn Pullets," by F. C. Bobby; (2) "Influence of Confinement on the Production of White Wyandotte Pullets," by Dorothy Macfadyean.)

The intensive system of poultry keeping is extending rapidly in the British Isles, with highly satisfactory results.

The advantages of the intensive system are—

1. A large number of birds can be kept when space is limited.
2. Parasitic infection is more easily controlled.
3. Labour can be reduced to a minimum.

The disadvantages of the intensive system are—

POULTRY (*Continued*)—

1. The system is not to be recommended for breeding stock.
2. Management under this system requires to be more highly skilled than under the two previously mentioned systems.

Housing—In order to obtain the high output of eggs expected from the domestic fowl (150 to 180 eggs per bird per annum as an average) the environment in which it is kept must be such that a maximum of comfort is provided, and the essentials of a good poultry house are that it is dry, well ventilated, but free from draughts, and well lighted.

In its construction care should be taken that all parts are easily accessible for cleaning, and such as will facilitate the work of the attendant.

Poultry houses are best constructed of tongued and grooved boarding ¾ to 1 in. in thickness, built up in sections on wooden framing, and the sections bolted together. Other materials may be used in poultry-house construction, such as straw thatched on to wooden framework covered with wirenetting, or bitumastic felting nailed to wooden frames; these latter, while cheaper in cost than boards, are less durable.

The semi-intensive type of poultry house, which has a lean-to, or preferably a span roof, and is about 6 ft. high to the eaves, is the one most to be recommended; 3 to 4 square ft. of floor space should be allowed for every bird, and one nest box for every four birds.

For egg-production the flock is best divided into units of not more than 100 birds, as this unit maintains the labour and capital cost at an economic limit, while so subdividing the whole of the stock that each unit can be efficiently supervised and any outbreak of disease confined within reasonable limits.

The slatted floor type of house has recently become more extensively used for housing laying birds, and it presents an economical form of housing; from ¾ to 1 square ft. of floor space is allowed per bird in this type of house. While it is not suggested that the slatted floor type of house can take the place of the large semi-intensive laying house, it can be recommended for housing growing stock, or for housing laying stock on free range on the general farm.

For details of construction and plans of poultry houses reference may be made to "The Planning of Poultry Houses," copies of which may be obtained from the Ministry of Agriculture, 10, Whitehall Place, London, S.W. 1.

The cost of housing per bird varies with the size of the poultry house, one holding twelve birds only being more costly per bird than a larger house to hold a greater number.

The cost of several sizes of poultry house, showing the cost per bird, is given on p. 969.

In calculating the actual cost of a poultry house when erected on the farm, several incidental expenses must be taken into account. Such are carriage, cartage from railway station, cost of material to raise the house clear of the ground, and labour of erection, amounting in all to, say, £6. The total cost of a house 30 ft. by 12 ft. by 6ft. high is thus approximately £60 10s.

POULTRY (*Continued*)—

Description of Poultry House.—Semi-intensive poultry house of span roof type 6 feet high to eaves, manufactured of ⅝ inch tongued and grooved boards on 3 by 2 inch framing complete with perches, dropping boards, nest boxes, and floor.

Size.	*Price of House.*	*Allowing 3 Square Ft. of Floor Space per Bird, to Hold—*	*Cost per Bird.*
	£ s. d.		s. d.
8 ft. 6 ins. by 7 ft.	16 16 0	20 birds	16 10
13 by 9 ft.	22 0 0	39 ,,	11 3
20 by 12 ft.	42 0 0	80 ,,	10 6
30 by 12 ft.	54 10 0	120 ,,	9 0
30 by 15 ft.	65 10 0	150 ,,	8 9

Hygiene—Provided a poultry house is so constructed that it is dry, well ventilated without draughts, and is so designed as to admit plenty of sunshine, cleanliness then completes the requirements for effective hygiene.

Dropping boards should be regularly scraped, preferably once daily, and fine sand scattered lightly over the board facilitates the work. The manure may be collected in a receptacle such as a dust bin outside each house, and this can be emptied each week, and the manure distributed on the land as required.

The litter used on the floor, for which wheat straw is the best material, should be cleaned out and replaced when damp or dirty; in a well-ventilated house it will last several months.

Whenever the litter becomes damp within a short time of renewal, and no leakage into the house of rain can be found, the cause can usually be traced to insufficient or wrong ventilation.

Nesting boxes should always receive particular attention, for it is here that hen fleas will breed and multiply rapidly in warm weather, and when broody hens are common. When hen fleas are present in the nests the eggs become marked with characteristic black specks and smears.

Once yearly, preferably during the summer months, or whenever special measures have to be taken to combat infectious or contagious disease, the poultry house should receive a very thorough cleansing.

All litter should be removed, and the floor, dropping boards, and perches should be scraped clean of adhering dirt. It is desirable to scrub the interior of the house and fittings with water, to remove dirt not already removed by scraping, and to follow this with a spray of a strong solution of any recognized disinfectant, and allow to dry for a few hours before putting in new bedding.

Creosote should be applied to the perch sockets and to the underside of the perches to keep red mite in check.

The land over which the fowls run should be maintained in good

POULTRY (*Continued*)—

condition by avoiding overcrowding, and thus preventing the herbage from being completely destroyed, but if 16 to 20 square yds. of grass run are allowed per bird, this should not occur. The duplicate runs provided under the semi-intensive system are of great assistance in maintaining the herbage in a healthy condition.

Incubation and Rearing—In recent years artificial methods of hatching and rearing chickens have largely taken the place of the natural method of using broody hens. The perfection of artificial methods of incubation and rearing, the elimination of the broody factor, and the economic necessity for hatching chickens at a time of year when few hens are broody, are all factors which have influenced the extensive use of incubators and artificial brooding appliances.

There are several types of incubator in general use which are capable of taking, according to their design, from 25 up to 16,000 eggs at one time.

The choice of incubator must rest with the individual according to his needs, and full working instructions are issued by the maker.

Variations in the management should be made only when good results are not being obtained, as may be the case where the incubator room is not an ideal one.

The temperature at which the thermometer in the incubator should be maintained will vary from 100° to 104° F. in the different types of machine, but the makers' instructions will indicate the most desirable temperature.

Moisture is a factor largely influencing results in incubation, and closely related to moisture is ventilation. By keeping the floor wet, moisture may be increased in the atmosphere of the incubator room, so that more moisture enters the incubator with the intake of air. The necessity for increasing the moisture in the atmosphere is greater in cold weather than in warm.

Once the hatch has commenced, as indicated by the pipping of the shell by the chicken, the incubator should be closed, and remain so until the hatch has completed.

An incubator room where an even temperature of from 60° to 70° F. can be maintained is desirable and even necessary for some makes of incubators, but many incubators are capable of giving good results in rooms where the temperature varies considerably. There should be sufficient ventilation to carry away impure air.

The care of hatching eggs should be given due consideration, as their hatchability may be greatly affected if badly stored. They are best stored in their natural position on their side, and should be placed away from draughts in a temperature between 50° to 60° F. if possible. More damage to the hatchability is likely to occur if the eggs are stored at a temperature of 70° F. than at 40° F. If properly stored, eggs appear to deteriorate little in hatchability up to about seven days, from then up to twelve to fourteen days a gradual decline in the hatchability takes place, after which time the decline becomes more rapid.

POULTRY (*Continued*)—

A table of incubation periods for eggs of the various domestic poultry is given below:

Fowl	21 days
Duck	28 ,,
Goose	30 ,,
Turkey	28 ,,
Guinea fowl	26 ,,

The cost of an incubator will vary according to its capacity and manufacture, but reliable machines can be obtained from the following prices:

100 egg capacity	£5	or at a cost of	1s. per egg capacity.
150 ,, ,,	£6	,, ,,	9½d. ,, ,,
900 ,, ,,	£45	,, ,,	1s. ,, ,,

The running cost in fuel consumed will vary from 1d. per day in the case of the 100 eggs capacity incubator to 1s. per day in the case of incubators of from 1,200 to 3,600 eggs capacity.

Breeding—In establishing and maintaining a flock of laying birds capable of producing a high average annual output of marketable eggs, it should be remembered that no one breed is far outstanding all others in this respect, but that several of the breeds which are more extensively kept, and which have undergone much selective breeding for high egg-production, vie closely with each other in respect of egg output, and that strain then becomes all-important.

The capacity for high egg-production, combined with such attributes as size of egg and colour of eggshell, are definitely inherited characters (see R. C. Punnett, "Heredity in Poultry"; C. C. Hurst, "The Genetics of Egg-Production in White Leghorns and White Wyandottes," *Trans. Inst. World's Poultry Congress*, vol. i.; L. Pearl, "The Inheritance of Fecundity in the Domestic Fowl," *Maine Agric. Expt. Stat. Bull.*), and unless the ancestors on both sides have excelled in the desired characters their progeny cannot be expected to inherit in a high degree the qualities which are most desired.

The economic results from poultry farming depend not only on a high average production being obtained, but also upon a fair proportion of the total eggs produced being laid during the months of the year when egg prices rule highest, viz., October, November, December, January, and upon the produce being of the size for which the greatest demand exists, viz., 2 to 2¼ ozs.

It is from the pullet flock that the highest proportion of eggs in the winter months is expected, and in order that the pullets may commence production by the latter part of September they must be hatched not later than the first week in April in the case of sitting breeds, and not later than the end of the first week in May in the case of non-sitting breeds.

Breeding stock should be selected after due consideration has been given to information gained by an examination of each bird; considering at the same time information supplied by trapnest and pedigree records if these are available.

POULTRY (*Continued*)—

The following table indicates various points which the breeder should use to assist him in his selection:

From an examination of the individual.	Breed and varietal characteristics.	
	Physical characteristics.	Vigour and vitality. Body size. Body conformation. Absence of deformity. Temperament.
From an examination of book records.	Laying performance.	Total number of eggs laid. Eggs laid during winter period. Size of egg. Colour of eggshell.
	Broody instinct.	
	Ancestry record.	
	Age at sexual maturity indicated by first egg.	
	Quality of sisters and brothers.	
	Fertility and hatchability of eggs.	
	Vigour of progeny.	

Where no book records are available selection necessarily rests solely upon the judgment of the poultryman when examining each individual, and certain characteristics are associated with high egg-production; amongst which are refinement of the head, which should show a smooth face having clear and prominent eyes. The comb and wattles should be well developed, but not coarse; they should be smooth, with the absence of wrinkles or puffiness. The plumage should be close and silky to the touch.

Hens in their second year are more desirable as breeders than pullets, although the latter may be used after they have reached the age of ten months. Male birds about ten months of age as a rule give more fertile mating than males two or more years old. The number of females mated to one male depends largely upon the individuals, but from 8 to 12 females of a sitting breed or from 10 to 15 females of a non-sitting breed are matings usually used, although in a flock where several males are mated to a number of females a greater proportion of females than those indicated may be allowed.

In breeding operation the most desirable method to adopt is to mate one male to the number of females indicated, in separate pens; but upon the general farm the method adopted may be the mating of 50 to 120 females to several males, in the proportion of about 8 males to every 100 to 120 females.

Chicken Rearing—As a rule, where hatching by hens is the practice, the natural method of chicken rearing by hens is used, the hen being placed within a chicken-rearing coop about 2 ft. square. The hen should not be given free range from the coop, as she will frequently spend much time in wandering about scratching for food, and the young chickens will be exposed to cold winds and bad weather conditions, and by reason of their small size may not be able to keep pace with the hen.

POULTRY (*Continued*)—

Although the hen is confined to the coop, the chickens may be given limited range into a wirenetted run, or they may be allowed free range. The methods of feeding chickens reared by hens are the same as those later outlined for chickens reared by artificial methods.

Rearing by Artificial Appliances—Appliances for artificial rearing may be divided into four main classes:

1. Brooders or foster-mothers, which are solely of use for rearing young chickens until they are about eight weeks of age. These are usually about 6 by 3 ft. by 2 ft. 6 ins. in height, being constructed of wood, with one end partitioned off and containing some arrangement for radiating and conserving heat, which is supplied by an oil lamp. The brooder, if of good manufacture, may be relied upon as a sound rearing appliance. Brooders are not serviceable for housing chickens after they are about eight weeks old, and consequently more capital will lie idle between chicken-rearing seasons if brooders rather than portable stoves are used.

2. Portable hovers capable of brooding up to 150 chickens, the heat being supplied by a paraffin oil lamp. These are suitable for use in small poultry houses, 6 by 4 ft. or larger in size, or in partitioned sections in a brooder house. The portable hover of good design is the most serviceable of all rearing appliances, and, except where very large numbers of chickens are being raised, is the appliance most to be recommended. The hovers themselves are not very large, and occupy little space when stored between seasons. The house in which they are used for chicken rearing is serviceable at other times for housing adult stock.

3. Large hovers capable of brooding 250 or more chickens. These are suitable for use only where a considerable number of chickens are being reared each year. For their use chicken-rearing houses 8 by 8 ft., or larger, in size, or a brooder house divided into sections, are necessary.

There are three main types of these large hovers:

- i. The anthracite stove.
- ii. The paraffin-burning " blue flame " hover.
- iii. Hot-water pipes heated from a coke or anthracite coal burning stove.

4. Battery brooders. This system is of very recent introduction, but is being adopted with considerable success in numerous instances where large numbers of chickens are reared.

In this system compartments having wirenetted floors, under which are trays to collect excrement, are stacked in tiers of four or five. The heat is provided by hot-water pipes above each compartment, or the whole room in which the batteries are placed is kept at the required temperature by circulation of warmed air.

The table on p. 974 shows the approximate advertised capacity and prices of the various chicken-rearing appliances, together with the approximate consumption and cost of fuel per week.

POULTRY (*Continued*)—

Chicken-Rearing Appliances.	*Chicken Capacity.*	*Price.*	*Fuel Consumption per Week.*	*Price of Fuel on the Farm.*	*Cost of Fuel per Week.*
Brooder and foster-mother	100	£5 12s. 6d. to £6 10s.	5 to 8 pints	1s. per gallon	7d. to 1s.
Portable hover ..	100	£2 5s. to £2 10s.	4 to 6 pints	1s. per gallon	6d. to 9d.
	150	£2 10s. to £3	5 to 8 pints	1s. per gallon	7d. to 1s.
Anthracite stove ..	500	£5 to £6	140 to 160 lbs.	55s. per ton	3s. 6d. to 4s.
	1,000	£6 15s. to £8 10s.	220 to 240 lbs.	55s. per ton	5s. 6d. to 6s.
"Blue flame" paraffin-burning stove	200 to 400	£5 10s. 0d.	4 to 6 gallons	1s. per gallon	4s. to 6s.
	400 to 600	£6 10s. 0d.	5 to 8 gallons	1s. per gallon	5s. to 8s.
Hot water hovers heated by anthracite stove	1,000	£48	220 to 240 lbs.	55s. per ton	5s. 6d. to 6s.
Battery brooder ..	1,600	£80 to £90	220 lbs.	55s. per ton	5s. 6d.
	3,200	£134 to £175	260 lbs.	55s. per ton	7s.

The successful rearing of young chickens is the most difficult operation on the poultry farm and requires keen observation and attention to detail.

The requirements for successful chicken rearing are essentially those of good housing combined with suitable temperature and proper feeding.

Before young chickens are placed under any brooding appliance, a temperature of 90° F. should be attained with the bulb of the thermometer placed at about the position at which a chicken would stand. Once the chickens have been placed under the appliance, the experience of the attendant should be relied upon to judge by their behaviour whether the temperature is satisfactory. If the chickens crowd together nearest the warmth and chirp they are too cold, whilst if they spread out far away from the source of heat they are too warm.

As the chickens increase in size less heat is necessary, and the temperature should be reduced gradually until they are about eight weeks old, when, except in the event of very severe frost, they require no artificial heat.

In advertisements the capacity of brooding appliances is usually overrated, and while an appliance may be suitable to hold the number of chickens for which it is advertised for the first week or two of their lives, their rapid increase in size necessitates the adoption of some means of preventing overcrowding; they may thus require to be divided between two brooding appliances.

POULTRY (*Continued*)—

One-half to one square ft. of floor space should be allowed per chicken in the rearing house until the chickens reach the age of eight weeks.

The first fourteen days is the most critical stage of a chicken's life, and they are susceptible to various diseases peculiar to chickens until they are about eight weeks of age, but by good management and hygiene these may be avoided.

Ground to which chickens suffering from disease have had access cannot be disinfected thoroughly by practical measures, and where clean ground is not available chickens may be reared intensively until they are eight weeks old and have passed the age when most susceptible to the diseases causing high mortality to young chickens, such as gapes or coccidiosis.

When the intensive system of rearing is practised plenty of floor space should be allowed in the house, at least ½ to 1 square ft. per chicken, and cod-liver oil should be added to the rations, at the rate of 1 per cent. of the total food consumed, to prevent leg-weakness.

As a bedding for young chickens wheat straw chop is best, or as an alternative oat straw chop, but where neither of these is obtainable peat moss litter may be used.

Cockerels should be segregated as soon as they can be recognized at from eight to fourteen weeks of age, and those not required as stock birds should be fattened for market.

Chicken Feeding—For young chickens it is important that the foodstuffs should be wholesome and highly digestible. The ingredients need not be of a costly and fancy nature, such as millet, canary seed, for suitable rations can be of simple composition. The size of the grain mixture should vary according to the age of the chickens, and on this account wheat and maize are broken to a suitable size.

All feeding and water utensils should be scrupulously clean.

Chickens do not require feeding until they are thirty-six hours old. The first few feeds should be given on boards, and these replaced by troughs or dry mash hoppers as soon as the chickens are feeding freely. Water and a limestone grit should be placed where they are easily accessible. The provision of sufficient trough or hopper space cannot be over-emphasized.

Three systems of chicken feeding are in general use in the British Isles.

Grain and dry mash method.
Grain and wet mash method.
All mash method.

Grain and Dry Mash Method—This system is one which can be recommended, and it is the one most extensively in use at the present.

The dry mash is supplied in suitable troughs or hoppers so that the chickens may obtain it at any time. Two or three feeds of the grain mixture are given daily, usually as a scratch feed in the litter.

Grain and Wet Mash Method.—The mash mixture is mixed to a crumbly consistency with water, and is fed in troughs alternately

POULTRY (*Continued*)—

with the grain mixture. Only as much mash should be given at each feed as the chickens will consume in ten minutes. The intervals between feeds should be two hours until the chickens reach six weeks of age, when the interval may be extended up to three hours.

All-Mash Method—This system is of recent introduction, and has not yet been widely tested in practice. It is reported, however, to be giving excellent results, and although from the experimental data available it has not proved to give quite so good results as the mash and grain systems, the results compare very favourably.

RATIONS FOR CHICKENS.

Chicken Grain Mixture.

	Parts by Weight.	
Broken wheat	2	up to 6 weeks of age.
Pinhead oatmeal ..	2	
Finely broken maize	1	
Whole wheat ..	2	from 6 weeks upwards.
Broken maize ..	1	

The following are rations which can be used in conjunction with the grain mixtures already indicated, and can be fed as dry or wet mash:

Chicken Mash Mixtures.

	Parts by Weight.
Yellow maize meal	46
Thirds	20
Sussex ground oats	20
*Meat and bone meal	10
Mineral mixture ..	
Cod-liver oil	

	Parts by Weight.
Thirds	4
Yellow maize meal ..	
Sussex ground oats	
Bran	1
*White fish meal ..	
Cod-liver oil (per cent.)	

	Parts by Weight.
Thirds ..	20
Yellow maize meal	20
Sussex ground oats	20
†Dried skim milk	10
*Meat meal ..	10
Linseed meal	3
Mineral mixture (per cent.)	4

Mineral Mixture.

	Parts by Weight.
Charcoal	1
Steamed bone flour.. ..	1
Precipitated chalk	1
Common salt	½

The table on p. 977 shows the average weight of chickens at various ages, and the approximate average food consumption.

Systems of Feeding for Laying Birds—Three systems of feeding laying birds are in general use; these are:

Grain and wet mash.
Grain and dry mash.
Grain and dry mash with supplementary wet mash.

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* After ten weeks reduce the meat meal, meat and bone meal, or white fish meal to half.

† After twelve weeks omit the dried skim milk.

POULTRY (*Continued*)—

	Sitting Breed.			*Non-sitting Breed.*		
Age.	*Average Weight of Chicken.*	*Average Weight of Food Consumed.*	*Average Cost of Food at 16s. 4d. per Cwt.*	*Average Weight of Chicken.*	*Average Weight of Food Consumed.*	*Average. Cost of Food at 16s. 4d. per Cwt.*
At hatching	1½–1¾ ozs.	—	—	1½–1¾ ozs.	—	—
8 weeks ..	15–17 ozs.	3½ lbs.	6d.	13–15 ozs.	3 lbs.	5¼d.
12 ,, ..	2 lbs.	8½ lbs.	1s. 3d.	1¾ lbs.	6½ lbs.	11½d.
16 ,, ..	3¼–3½ lbs.	13 lbs.	1s. 8¾d.	2–2¾ lbs.	11 lbs.	1s. 7¼d.
20 ,, ..	4–4½ lbs.	20 lbs.	2s. 11d.	2½–3¼ lbs.	15½ lbs.	2s. 3d.

The same rations may be used whatever the system, but it must be remembered that as the mash is the portion of the ration through which additional protein is supplied, the ratio of grain to mash consumption is important, and rations are usually balanced on the assumption that approximately 2 ozs. of grain are consumed by each bird per day, in addition to 2 to 2½ ozs. of mash, and that the average egg production will not exceed 200 eggs per bird per annum. (See Poultry Nutrition.)

No rule of thumb methods can be laid down, but the attendant must use his observation and discretion in the light of his experience.

During the cold winter weather more grain than is indicated may be consumed, and a frequent practice, during the winter months, is to supply as much grain at the evening feed as the birds will consume.

The best results are obtained by the grain and dry mash system, giving a supplementary feed of wet mash at midday during the winter months. Dry mash should be available all day. A small grain feed at the rate of about 4 lbs. per 100 birds should be given in the morning. During the winter months a wet mash should be given in troughs at midday, supplying about 6 lbs. of the mash weighed dry per 100 birds, or less if this is not consumed in about fifteen minutes. The remainder of the grain ration is given late in the afternoon. During the winter months the birds may have as much of this evening grain feed given in troughs as they will consume, or during the summer months from 8 to 10 lbs. per 100 birds.

Limestone grit should be available in boxes, and clean water should be supplied so that the birds may obtain them at any time, particular care being taken that the water troughs do not become dry during the summer, and in frosty weather that the ice is thawed, if necessary, several times daily, as water is as important as food for egg production.

Artificial Lights for Increasing Egg Production—Egg production of fowls of high fecundity is largely dependent upon a large consumption of food, and during winter, when the length of daylight is curtailed to eight to ten hours, the quantity of food a bird will consume is limited to the time during which it can see to feed. By lighting the poultry

POULTRY (*Continued*)—

house with artificial light, so as to extend the feeding day, the egg output can be considerably increased.

In the use of artificial lights several essentials are necessary for success, viz.:

1. Proper illumination. One 40-watt electric lamp, or one double-burner acetylene lamp, will be necessary for every 200 square ft. of floor space, on an area 14 × 14 ft.
2. The light before it is extinguished should be dimmed sufficiently for the birds to see their way back to the perches.
3. Food and water should be available as soon as the light is switched on, dry mash in the hoppers and grain in the troughs.

There are several methods of lighting:

1. By switching on the lights for half an hour at about 9.30 p.m., and this is most to be recommended.
2. By lighting up early in the morning, say at 4 a.m., and continuing the light until daybreak.
3. By lighting up at dusk and continuing the lights until 8 p.m.
4. By a combination of methods 2 and 3, allowing two hours of illumination in the evening and a similar time in the morning.

Rations for Laying Birds—Wheat, broken yellow maize, and oats are the three cereals most suitable for the grain portion of the laying hen's ration. Oats, on account of their bulk and high proportion of husk, are best reserved for feeding only during the warmer weather.

Wheat and broken yellow maize in equal proportions make a very suitable grain ration for the winter months, from October to March, whilst wheat, broken yellow maize, and oats in equal proportions are suitable for use during the remaining portion of the year.

Several mash mixtures are given below, which may be fed dry or mixed with water as a wet mash:

	Parts by Weight.
Thirds	40
Yellow maize meal	25
Sussex ground oats	10
Bran	10
Alfalfa meal	5
White fish meal	10

	Parts by Weight.
Thirds	4
Yellow maize meal	3
Bran	1
White fish meal	1

	Parts by Weight.
Thirds	4
Yellow maize meal	2
Sussex ground oats	1
Bran	1
White fish meal	1

	Parts by Weight.
Ground wheat	28
Ground oats	25
Ground barley	20
Ground peas	15
White fish meal	10
Mineral mixture	

Mineral Mixture.

	Parts by Weight.
Steamed bone flour	10
Chalk	2
Common salt	2
Sulphur	1
Ferric oxide	1

POULTRY (*Continued*)—

Meat meal, which should contain not less than 50 per cent. protein, may replace white fish meal part for part, but the ration should also include 2 per cent. of mineral mixture.

Soya-bean meal may also be used to replace white fish meal, using 1⅓ parts of soya-bean meal for each part of white fish meal replaced, and adding 2 per cent. of mineral mixture to the ration.

A laying bird will consume from 85 to 95 lbs. of food per annum, and if this costs 12s. per cwt., the yearly cost of food per bird will vary from 9s. 1d. to 10s. 2d.

Marketing—The marketing of his products to the best advantage requires considerable attention from the poultry-keeper if the best prices are to be obtained, and the financial returns obtained by marketing the produce in the best possible way through the best markets will result in a considerably higher margin of profit being obtained.

In marketing eggs in the best possible condition, the following points should be observed:

1. Keep the nests clean and dry.
2. Collect the eggs at least once a day.
3. Stained eggs should be used in the farm household.
4. Slightly soiled eggs should not be washed, but should have the soiled portion wiped clean with a damp cloth.
5. Store the eggs in a clean, cool, dry place away from other material likely to impart a taint to the eggs, such as oranges, lemons, onions, paraffin, etc.
6. Eggs from "stolen nests" should be candled before marketing.
7. Market the eggs at least once each week.
8. Hen eggs and duck eggs should never be mixed.
9. Grade the consignment.
10. Market in clean containers of attractive appearance.

Accredited Egg Packing Stations, which exist throughout the British Isles, working under the National Mark Egg Scheme, have done much to further the efficient marketing of the home-produced egg, and about 250 million eggs were marketed under the Scheme during the first year of its operation, from February 1st, 1929.

Poultry marketed for table use must be prepared in an attractive manner, and in a form which meets the market requirement:

1. Old hens are usually best marketed alive.
2. Chickens should be marketed at the right stage, according to the market demand, which is for small birds up to three pounds each during the early months of the year, February to July, after which a larger chicken is in good demand.
3. When birds are marketed after killing, they should be fasted for from eighteen to twenty-four hours before being killed.
4. They should be killed either by dislocation of the neck or by sticking, and the proper method should be learned.
5. Pluck and stub carefully so that the skin is not torn.
6. Save the feathers in three lots: white body feathers, body feathers

POULTRY (*Continued*)—

other than white, and quills. The quill feathers are of small value, but the body feathers will be worth from 2d. to 8d. per pound, according to their condition and the state of the market. White body feathers are worth twice as much as coloured body feathers. The stubs should be kept away from feathers which are to be sold.

7. Shape by pressing or tying down in accordance with market custom.

8. Cool well and rapidly before packing.

Reference may be made to the "Report on Egg Marketing in England and Wales," and "Report on the Marketing of Poultry in England and Wales," published by His Majesty's Stationery Office. C. W. G.

POULTRY NUTRITION—In poultry keeping, vegetable and animal foods largely unsuitable for man are converted by the fowl into forms suitable for human consumption, *i.e.*, meat and eggs, and the poultry keeper's main object is to achieve this conversion as economically as possible. Research in poultry nutrition is mainly directed towards ascertaining the natural laws upon which such conversion depends, and investigating the consequences that result as the operation of these laws.

THE COMPOSITION OF POULTRY AND EGGS—

TABLE I

COMPOSITION OF WHITE LEGHORNS.

Sex.	*Average Weight.*	*Age.*	*Water.*	*Dry Matter.*	*Protein.*	*Fat.*	*Ash.*	*Feathers.*
	Grm.	Weeks.	Per Cent.	Grm.	Grm.	Grm.	Grm.	Grm.
	49	1	73·3	11·5	6·9	3·3	1·0	
Female ..	890	15	67·2	254	155	62	37	76
Male ..	1,200	15	67·9	345	223	74	46	82
Female ..	1,550	28	63·4	511	266	179	62	121
Male ..	1,930	28	68·4	542	376	70	95	164

The data given in Table I, which are obtained from unpublished work carried out by the author at Cambridge during 1924-25, illustrate several facts relating to the growth of the bird. Like other animals, the chief changes that occur during growth from chick to adult are:

1. Diminution in the water content of the carcase as age proceeds.

2. Rapid increase in protein, owing to formation of the muscular system of the body as live weight increases.

3. Increase in ash constituents of the body as the growth of the skeleton proceeds with increasing age.

It will be noted that the ash content increase is relatively more marked than the protein content increase as the bird approaches maturity.

POULTRY (*Continued*)—

This is due to the fact that, as growth proceeds, the growth of the skeletal and muscular systems takes place simultaneously, but the deposition of bone salts in the skeleton continues after cellular formation of bone and muscle has ceased. One very important fact is brought out that has not hitherto been demonstrated, *i.e.*, a differential composition of the body due to sex. It will be noted that, whereas in the cockerel the maximum fat production is reached at fifteen weeks, this is not so in the pullet, which continues to lay on fat in the body until it considerably exceeds that in the cockerel. From observations made by the author on both White Leghorns and Light Sussex, this increased fat production in pullets appears to be associated with egg-laying, and is probably characteristic of all breeds of poultry.

Change of Composition of Bird during Fattening—An important industry, the Sussex fattening industry, is carried on in various parts of England, particularly the Heathfield district of Sussex. In the process of fattening, semi-mature and mature birds in store condition are force-fed by cramming machines with wet mash mixtures which have for their basis mutton tallow, Sussex ground oats, and milk. The change that occurs in the carcase during this process is illustrated in Table II. by data obtained from an unpublished experiment carried out by the author during 1929 at Cambridge.

TABLE II

LIGHT SUSSEX COCKERELS.

		Percentage Composition of Carcase.		
	Average Dead Weight.	Water.	Protein.	Fat.
Unfattened	2,696 grms.	69·8	18·1	6·4
Fattened	3,026 ,,	64·6	18·3	13·5

These figures illustrate quite clearly that in the process of fattening the chief change that occurs in the composition of the carcase is the deposition of fat accompanied by a diminution in the water content. The percentage protein content shows little change. In the case in point, the actual increase of protein during fattening was 75 grms., and the increase of fat was 241 grms., per bird.

The Composition of the Egg—A typical hen's egg consists of an outer shell, a shell membrane consisting of two layers, a thick layer of albumen, and a central yolk. Towards the blunt end of the egg the two layers of the shell membrane separate and enclose an air space, which varies in size according to the age of the egg. The yolk is enclosed in a delicate vitelline membrane, and is suspended in the centre of the white or albumen by two chalazæ, or whitish, opalescent, twisted cords of thick albumen. The albumen is differentiated into two layers, a thick, dense layer surrounding the yolk itself, and a thinner watery layer adjacent to the shell membrane. Eggs vary in weight, but the average weight is approximately 2 ounces.

POULTRY (*Continued*)—

Chemical Composition—The shell, white, and yolk are present in the following percentage average proportions: shell, 13·5; white, 56·5; yolk, 30.

Over 89 per cent. of the shell consists of calcium carbonate, the rest being made up of approximately 6 per cent. of phosphates of calcium and magnesium, and 5 per cent. of organic matter and sulphur-containing substances.

The egg white is a yellowish or greenish albuminous fluid consisting chiefly of gluco-proteins; ovalbumin, ovoglobulin, conalbumin, and ovomucoid having been isolated by various workers.

The yolk is an alkaline viscous emulsion consisting chiefly of water, fats, ovovitellin, cholesterol, lecithin, etc.

An analysis of fresh eggs carried out at Cambridge by H. G. Pike was as follows:

	Per Cent.
Water	70·5
Fat (ether extract)	8·6
Protein	11·0
*Ash	7·6
Undetermined	3·3
	100·0

*Containing:	Insoluble matter	0·010
	CaO	4·508
	P_2O_5	0·512
	Sulphur (S)	0·214
	K_2O	0·175
	Na_2O	0·263
	Cl	0·150
	Fe	0·0005

Effect of Feeding on the Colour of the Yolk—Recent research has demonstrated beyond doubt that the colour of the yolk is controlled by the nature of the food fed. Birds of any breed kept under confined conditions and fed on foods such as wheat, oats, rice, barley, meat meal and fish meal, or dry milk products, always produce eggs the yolk of which will be almost white or of a pale lemon colour. The colour of the yolk is consequently a food characteristic and not a breed characteristic. If such birds are kept on free range, where liberal supplies of grass are available, the yolks will be a rich orange yellow. Similarly, if the diet contains liberal supplies of yellow maize, the yolks will be distinctly yellow, and a similar effect will be produced where alfalfa meal or supplies of green food are given. The colour of the egg yolk is due to the colouring matter that is contained in the food being transferred to the fatty material present in the yolk, the colouring matter in the green food that gives the desirable yellow colour in the yolk being known as xanthophyll (C. A. Schunk, *Proc. Roy. Soc.*, p. 170, 1904). Fat-soluble dyes such as Sudan III. are readily transferred to the yolk, and if small quantities of Sudan III. are fed to a laying bird, the yolks produced will be red in colour. Certain food substances if fed to birds will produce yolks of an

POULTRY (*Continued*)—

undesirable colour. Thus acorn meal will give rise to brownish-coloured yolks, and Payne has shown that birds eating shepherd's purse (*Capsella Bursa-pastoris*) and pennycress (*Thlaspi arvense*) will produce olive-coloured yolks (L. F. Payne, "The Cause of Olive-Coloured Yolks," *Poultry Science*, vol. iv., pp. 102-108). Lippincott also states that birds fed liberally on linseed oil meal will frequently give eggs with greenish-coloured yolks (Lippincott, "Poultry Production," p. 476). (For changes during cold storage see Refrigeration.)

THE DIGESTIVE SYSTEM OF THE BIRD—The digestive system of the bird is comparatively simple. The pointed horny beak is peculiarly suitable for use in picking up grains and small particles of food. The mouth leads to a short, wide gullet or œsophagus which enlarges at its lower end into a pear-shaped crop. The crop acts as a store for the food swallowed by the bird, and hard grains while in the crop undergo a certain amount of softening and swelling owing to the action of the secretion of the glands of the mouth, the gullet and the crop, and the liquids swallowed. The pear-shaped crop communicates by means of a short, wide tube, a continuation of the œsophagus, with the true stomach or proventriculus. The proventriculus is a thick, muscular tube containing secretory glands which give rise to abundant supplies of gastric juice. At its latter end the proventriculus communicates with an extremely muscular gizzard, which is a lenticular-shaped organ the inner lining of which is horny in character. The presence of grit and partly ground food material in the gizzard shows that it acts as a grinding or crushing organ. The gizzard communicates with a long, tortuous tube known as the small intestine, and into the first loop of this small intestine, the duodenum, communicating ducts of the pancreas and gall bladder open. The pancreatic juice of the pancreas and the bile of the liver reach the interior of the small intestine by means of these ducts. The latter end of the small intestine communicates with a comparatively short, large intestine, and its two blind appendages, the cæca. The end portion of the large intestine receives the two ureters from the kidneys, and terminates in the cloaca or vent, which is the external anal opening of the digestive tract.

Digestion and Fate of Foodstuffs—Food swallowed by the bird either passes into the gizzard direct or falls into the crop. In the case of a starved bird, the normal course of events is that the first two or three mouthfuls swallowed pass straight to the gizzard. As soon as the gizzard is full, the food begins to pass into the crop, which gradually fills. The gizzard now begins a series of slow, grinding movements, and the food within its interior is rapidly reduced to the consistency of a creamy mass. As soon as this stage is reached, the food mass is passed on into the small intestine and a new bolus of food is forced from the crop into the gizzard. In its passage to the gizzard the bolus passes through the proventriculus and stops about one inch from the gizzard entrance for about seven seconds, receiving abundant supplies of gastric juice while doing so, and then suddenly passes on into the gizzard. It is important to realize that, unlike the mammalia,

POULTRY (*Continued*)—

food does not remain for any appreciable length of time in the true stomach of the bird. This series of operations is continued so long as food remains in the crop. Keith Card and Mitchell (*J. Agric. Res.*, xxxiv., 759, 1927) have shown that in the case of whole maize this process occupies from twelve to fifteen hours, since a bird fed on 50 grms. of whole maize empties its crop within this period of time. The finely comminuted food mass as soon as it reaches the small intestine becomes intimately mixed with the bile, pancreatic juice, and the succus entericus, this latter digestive juice being secreted by glands situated in the walls of the intestine itself. The gizzard is a very efficient grinding organ, experiments carried out by the author (Halnan, "A Note on the Function of the Gizzard in Fowls," *The Harper Adams Util. Poult. Journal*, x., No. 12, 1925) having shown that the gizzard exerts a pressure approximating 40 to 50 lbs. on the food material within it. The grit present in the gizzard aids its efficiency by multiplying the surfaces of contact with the food mass. The effect of the digestive juices of the small intestine is to convert the insoluble proteins, fats, and carbohydrates of the food into soluble materials which are then absorbed by the walls of the gut and eventually pass into the blood stream of the animal. The indigestible residue of the food is finally excreted together with any excretory products of urinary origin. The two blind tubes or cæca, present as appendages of the large intestine, act as water absorbing organs, and according to recent German work, a certain amount of digestion of woody fibre and protein occurs here.

The passage of food through the small and large intestine is comparatively rapid. Steinmetzer (*Pflüger's Arch.*, ccvi., 500, 1924), using X-ray methods, showed that a bolus of food traversed the entire digestive tract within two hours. This observation has been corroborated and confirmed by similar work carried out at Cambridge.

The Rôle of Fibre in Poultry Nutrition—The extreme rapidity with which the food passes through the digestive tract of the fowl, coupled with the entire absence of cellulose splitting enzymes in its digestive juices, would lead one to expect little or no digestion of woody fibre to occur in the fowl. This expectation is confirmed by digestibility determinations, which, taken as a whole, indicate that no digestibility of fibre takes place in the fowl. On the other hand, Henning (H. J. Henning, "Die Verdaulichkeit der Rohfaser beim Huhn.," *Land. Vers. Stat.*, cviii., 253, 1929) has produced evidence to show that, in the case of some feeding stuffs, digestion of the woody fibre does occur to a certain extent, and the cæca have been assigned as the seat of such digestion. Work carried out by the author (Halnan, *J. Agric. Sci.*, xviii., 638) indicates that not only is woody fibre itself not digested, but that its presence in a feeding stuff leads to the depression of the digestibility of the other nutrients. The presence of woody fibre in foods intended for fowls is therefore undesirable, except in so far as it is necessary as a bulk constituent of foods, and it follows that fibrous feeding stuffs are unsuitable for use in poultry feeding.

POULTRY *(Continued)*—

Digestibility from a Practical Standpoint—Consideration of the several facts mentioned above leads to several important conclusions. First, the increased efficiency of the gizzard due to the presence of grit indicates the necessity of supplying grit to fowls under conditions where a natural supply is not available, *i.e.*, where birds are kept under intensive conditions or where kept on heavy clay ground. Secondly, the small capacity of the digestive system, and the inability of the bird to digest woody fibre, necessitates the restriction of foods for birds to those possessing little woody fibre and high digestibility. Thirdly, owing to the fact that only the digestible portion of the feeding stuff is available for metabolic purposes, the value of a feeding stuff should be based on its digestible nutrients, and not upon its crude chemical analysis.

NOTES ON FEEDING STUFFS FOR POULTRY—General Considerations—The nutritive value of a feeding stuff depends upon its content of protein, fat, carbohydrate, ash, and vitamins, as well as upon its peculiar dietetic effects. The biological value of a protein is partly qualitative in character and partly quantitative, but owing to the fact that in a normal mixed ration mixed proteins are fed, the qualitative character of the protein fed may, as a general rule, be ignored in practice, and consideration of its value can be confined to the quantitative point of view.

The protein, fat, and carbohydrates fed are energy producers, and from the energy standpoint the quantitative character of these substances need only be considered. Both vitamins and ash constituents are rather qualitative in character, their inclusion in a ration and their value being dependent entirely upon the metabolic needs of the animal. For this reason, in the establishment of a feeding standard, the protein and energy requirements only are treated from a quantitative standpoint, care at the same time being taken to ensure that the ration fed contains the amount of vitamins and ash constituents necessary to ensure normal growth or production.

Feeding Stuffs regarded from the Poultry Feeding Standpoint—*Alfalfa Meal*—Made from fresh cut lucerne by drying processes followed by treatment by disintegrators. Good samples containing a large proportion of leaf to stem are rich green in colour. Owing to its high fibre content, should be sparingly used in poultry rations. Is valued for its ash content and its effect on yolk colour in the case of hens kept under intensive conditions.

Barley and Barley Meal—Provided discretion is used, forms a useful grain or meal for poultry feeding. Is apt to be dangerous if fed in large quantity, or if care is not exercised to feed only samples properly cleaned and free from awns. Prejudice against its use for feeding is due to abuse in feeding. The meal is very suitable for inclusion in fattening mashes.

Beans and Bean Meal—A protein-rich food, suitable for use with poultry if supplemented by the addition of minerals.

POULTRY (*Continued*)—

Biscuit Meal—Much esteemed for use with chicks and high producing hens. A carbohydrate-rich food, and owes its popularity to its high digestibility and freedom from woody fibre. Its high price makes it uneconomic except under special circumstances.

Blood Meal—A very rich protein food, but rather unpalatable. Should only be included in poultry foods to a restricted extent.

Buckwheat and Buckwheat Meal—A suitable cereal for admixture with other grains. Is specially valued for inclusion in fattening mashes; its extensive use is stated to improve the whiteness of the flesh.

Earthnut Cake Meal—A rich protein food, suitable for partial replacement of animal protein in poultry rations, especially if supplemented with minerals.

Dari—A cereal akin to wheat in composition and value, and may be used freely for all classes of poultry.

Cotton Seed Meal—Used in the United States as a protein supplement, but the evidence available does not warrant its general adoption for poultry feeding.

Fish Meal—A protein-rich food, in general use for all classes of stock. Is valued both for its protein and its mineral content. Should be light in colour, and low in oil and salt content. It has been used up to 10 per cent. in a ration without affecting either the flavour of eggs or meat.

Groats—A valuable grain food for poultry, but its price renders it uneconomic except for use with young chicks. Is of special value for young growing chicks.

Maize and Maize Meal—A highly digestible cereal grain, and a carbohydrate-rich food, low in woody fibre content. Is specially suitable for poultry feeding, and its price has led to its extensive use for all classes of stock. The yellow varieties are of special value for laying stock, owing to their favourable influence on the yolk colour. For inclusion in fattening mashes, meal made from the white varieties only should be used, particularly with yellow-legged breeds, owing to the tendency of the yellow meal to colour the flesh.

Maize, Flaked—A highly digestible carbohydrate food. Owing to the horny character of the flakes, poultry dislike it if it is fed dry. Its use is warranted in chick mashes and in the case of high producing hens.

Maize Gluten Feed and Maize Gluten Meal—Protein-rich foods, obtained as by-products in the manufacture of glucose and maize starch. Are variable in composition, and do not keep well. Owing to the similarity of composition of the maize protein to other cereal proteins, is not suitable for inclusion with other cereals, unless used in conjunction with animal proteins.

Meat Meal—An extremely valuable protein-rich food, suitable for inclusion in cereal rations. Mineral supplements should be added when it is used for poultry feeding.

Meat and Bone Meal—A very useful protein-rich food, but owing to the variable amounts of bone present, should always be purchased

POULTRY (*Continued*)—

on a protein percentage basis. The inclusion of bone renders it very suitable for use with laying and growing stock.

Milk and Milk By-Products—Owing to the biological value of milk protein, milk and milk by-products are extremely valuable for young growing stock. Their price militates against their general use except for very young chicks. In the case of dried whey the purchaser should remember that the proteins have to a great extent been removed in the process of cheese-making, and this product should be regarded as a carbohydrate food rather than as a source of protein.

Oats and Sussex Ground Oats—A very useful cereal grain, owing to its mineral content and its oil content. The high fibre content renders it less suitable for general use in poultry feeding than the other cereals, and poultry do not consume it freely if other cereal grains are available. Sussex ground oats consist of the whole oats ground to a very fine meal, and good samples are nutty in flavour and silky in texture. Is largely used in fattening mashes. Its iron content renders it a suitable cereal food for inclusion in rations for young growing stock where milk products are used as a source of protein.

Peas and Peameal—Protein-rich foods, suitable for inclusion in poultry rations if supplemented with mineral constituents.

Potatoes—A carbohydrate food, suitable for use when the price warrants. Should always be cooked before using, and owing to its physical character, necessitates being used as a wet mash.

Rice and Rice By-Products—Rice is a very digestible carbohydrate food, and is included in many proprietary chick foods. Its price militates against its general use in poultry feeding. Rice meal consists of a mixture of the bran and rice polish obtained from the de-husked seed in its preparation for human food. Is very rich in oil and is a source of vitamin B. Owing to the presence of oil, tends to go rancid very quickly, and will not keep well in storage.

Rye—A useful cereal akin to wheat in feeding value. Is not much used in this country, and, owing to the danger of contamination with ergot, needs care in buying and feeding.

Soya-Bean Meal (*extracted*)—A very useful protein-rich food. From a biological standpoint the protein approximates milk protein in value if used in conjunction with a mineral supplement consisting of calcium carbonate, steamed bone flour, and common salt.

Sunflower Seed Cake Meal—A useful protein food, but owing to its high fibre content, unsuitable for poultry unless the price warrants it. Samples low in fibre only should be purchased.

Wheat and Wheat By-Products—An extremely useful cereal grain, suitable for all classes of poultry stock. Wheat bran is a common constituent of all poultry mashes, but owing to its low digestibility is a relatively expensive food. It is useful for adding bulk to a mash, is readily eaten by young chicks, and, owing to its dietetic value, is largely used in chick mashes. Coarse middlings is a digestible food, contains a large proportion of the wheat germ, and is suitable for all classes of stock, particularly laying and breeding stock. Fine middlings

POULTRY (*Continued*)—

is very suitable for inclusion in the rations of laying stock, and is very digestible.

Sugar-Beet Pulp (*molassed*) is a by-product of the beet-sugar factories, and consists of the dried extracted sugar beet with molasses added. Is a carbohydrate food, and owing to its high fibre content is unsuitable for use by poultry.

Dried Yeast—A protein concentrate and a rich source of vitamin B. Is extremely useful as a supplement to other proteins for use in poultry mashes.

Millet, Bulrush—The millets are very useful as supplements to other cereal grains. They are very digestible, and are palatable to poultry. Bulrush millet approximates to wheat in feeding value, and is readily eaten by all classes of poultry. The small size of the grain renders it particularly suitable for admixture in chick feeds.

The Mineral Requirements of Poultry—Minerals play an important part in poultry nutrition. They form an important constituent of the body tissues and fluids, and the physico-chemical vital processes are controlled and influenced by the extent to which they are present in the body and cell fluids. They also form an important constituent in the skeletal framework of the body. Calcium, potassium, sodium, iron, magnesium, copper, iodine, sulphur, chlorine, and phosphorus have all been shown to play an important part in the normal metabolic processes of animals. These substances are present in the ash of foods commonly used for poultry feeding, and it has been found that, under certain conditions, supplementing the amounts supplied in the food by mineral additions tends to beneficial results. The body of the average pullet contains:

CaO	P_2O_5	S	K_2O	Na_2O	Cl_2
1 oz.	1 oz.	$\frac{1}{7}$ oz.	$\frac{1}{6}$ oz.	$\frac{1}{5}$ oz.	$\frac{1}{14}$ oz.

200 eggs contain:

CaO	P_2O_5	S	K_2O	Na_2O	Cl_2
18 oz.	2 oz.	$\frac{4}{5}$ oz.	$\frac{2}{3}$ oz.	1 oz.	$\frac{1}{2}$ oz.

It is obvious from these figures that a pullet laying 200 eggs a year must obtain a large proportion of the mineral constituents required from its food. It has been shown that the minerals required to be added to the foods given are calcium, phosphorus, sodium, and chlorine, and that these are best supplied in the form of oyster shell or limestone grit, steamed bone flour, and common salt.

The figures given in Table I. for ash indicate the extent to which ash is laid on in the body during growth, and emphasize the desirability of providing in the food given for the ash required by the growing bird.

The Nutritive Requirements of the Growing Bird—Growth in the early stages of a bird's life is extremely rapid, and the limiting factor is its capacity for the consumption of food. For this reason chick rations should be constructed of readily digested foods of high nutritive value.

POULTRY (*Continued*)—

There are no data available that enable us to predict with any precision the quantitative requirements of the chick for protein and energy, but by studying the changes in composition of the body that occur during growth, we are enabled to ascertain the extent to which the various body tissues are built up as age proceeds, and to construct rations which will provide the raw material necessary for such storage to take place. From such data the author was enabled to conclude that storage of ash was extremely active right up to twenty-four weeks of age, and that energy storage is active throughout the growth period. By considering these facts in relation to the normal food intake of the bird and the ration normally fed to chicks, the author concluded that food mixtures normally fed to birds in practice were deficient in protein in the early stages of growth, and deficient in ash constituents in the later stages of growth. The rations given in Table III. embody the results of this work, and have been found to give good results in practice. For the sake of convenience, the rations are stated in the form of an all-mash ration, but by suitable modification, upon which the County Poultry Instructor should be consulted, the table can be altered to allow for grain and mash systems of feeding.

TABLE III

DRY MASH CHICK-REARING RATIONS. (ALL-MASH SYSTEM, DRY FED.)

Food.	*Parts by Weight.*				
Age in weeks	**1-3**	**3-7**	**7-10**	**10-15**	**15-laying**
Maize meal	40	45	45	50	60
Bran	20	10	10	5	5
S.G.O.	—	10	15	15	10
Coarse middlings	20	15	15	15	20
Meat and bone meal (50 per cent. protein)	5	10	5	5	—
Dried skim milk	15	10	5	—	—
Extracted soya-bean meal ..	—	—	5	10	5
Common salt	1	1	1	1	1
Cod-liver oil	1	1	1	1	1
Steamed bone flour	—	—	2	2	2

Notes.—(1) The mash given is suitable for chicks reared under intensive conditions. If the chicks go out to grass, the cod-liver oil may be omitted, particularly in the later stages.

(2) The protein foods given are regarded as interchangeable, but when substituting soya-bean meal for meat and bone meal or dried skim milk, the need for supplementary mineral salts must be supplied. Owing to the variable biological efficiency of different proteins, it is desirable that the protein required should be supplied from several sources.

(3) Limestone grit or oyster shell must be supplied in a separate hopper in addition to the mash, particularly from seven weeks of age onwards.

(4) If grain is fed in addition to mash, the cereal mash ingredients are cut down in the mash in proportion to the grain fed.

Requirements during Moulting—In the adult bird, moulting is often induced by cutting out the protein foods in the ration. The feathers

POULTRY (*Continued*)—

of an adult bird represent approximately 4 to 5 ozs. of protein, and it follows, therefore, that unless the protein in the food is restored as soon as active moult commences, the period of re-feathering will be a prolonged one. The protein requirement for the new feathers represents on a 5 per cent. protein ration nearly thirty days' supply of food. Allowing twelve days for the formation of the yolk of an egg, it will be seen that a period of six weeks must inevitably elapse between the onset of moult and the re-commencement of laying in a bird kept on a protein-poor ration. As soon as moulting has fully set in, the bird should therefore be placed on a protein-rich diet in order to induce rapid re-feathering and to encourage the formation of fresh yolk material.

THE NUTRITIVE REQUIREMENTS FOR EGG PRODUCTION— General Consideration—The egg apparatus of the fowl consists of an ovary and an oviduct or Fallopian tube. The oviduct has a funnel-shaped opening in the vicinity of the ovary, and is differentiated into an albumen-secreting portion, an isthmus where the egg membranes are formed, and a shell gland in which the eggshell is secreted. The ovum in the ovary develops into an egg follicle, and if a bird in active laying is killed, several follicles will be seen in active development.

When the yolk is fully formed, the follicle splits along a pre-determined line and sets free the yolk, which then enters the funnel-shaped opening of the oviduct and gradually descends. In its descent it receives the white of the egg, the covering membranes, and the shell.

The ova develop in two stages. The first development occurs early in life, and the second development, *i.e.*, yolk formation, occurs when the bird reaches the mature laying condition. Riddle and other workers have shown that the yolk formation takes six to eight days, and that formation of the white and shell occupies eighteen to twenty-two hours.

The author (Halnan, *Harper Adams Util. Poult. J.*, x., No. 9, 1925) has shown by metabolic experiments that little or no preliminary storage of protein, calcium, and phosphorus takes place during egg formation, the storage being limited to seven to fourteen days before laying commences. From these facts it follows that the materials required for egg production must be provided in the food fed during actual egg production, and that there is no need to put the bird on a laying mash until the reddening and swelling of the comb indicates the commencement of yolk formation. Moreover, the physiological facts given show that one normal egg a day is the maximum egg production possible from a single bird.

The Quantitative Requirements for Egg Production—(1) *Shell Formation*—Nearly $\frac{1}{5}$ oz. of calcium is required for the production of the shell of the egg. The author has shown that the calcium required for its formation is readily taken from any calcium given in the food supply. On the assumption of a 4 oz. daily food consumption, at least 4 per cent. of calcium carbonate must be supplied in the

POULTRY (*Continued*)—

ration for shell formation unless the bird is supplied with a readily available source of calcium in the form of oyster shell or limestone grit.

(2) *Protein and Energy Requirements*—The ration fed to a laying pullet has to supply the materials required for (1) the maintenance of the body weight and vital activities; (2) growth requirements; (3) the physiological activities associated with egg laying. Professor Voitellier, in "Aviculture," gives estimates of those requirements for birds kept under French conditions. In 1928, the author, from consideration of such scientific data as were available, and of the results of British and Australian egg-laying trials, made very careful estimates of the protein and energy requirements of the laying hen, and the results of these investigations are given in Tables IV. and V.

TABLE IV

THE GROWTH AND MAINTENANCE REQUIREMENTS OF PULLETS PER BIRD PER DAY.

Weight of Bird.	*Digestible Protein.*	*Starch Equivalent.*
Lb.	Grm.	Grm.
3	6·5	51·7
4	7·4	58·1
5	8·3	64·1
6	9·2	69·7
7	10·1	75·0
8	11·0	80·0

TABLE V.

EGG PRODUCTION REQUIREMENTS PER 2 OZ. EGG.

Digestible Protein.	*Starch Equivalent.*
Grms.	Grms.
15·0	40·0

(28·35 grms.=1 oz.)

For details as to the use of Tables IV. and V. in the checking of rations in use and the construction of rations for laying birds, readers are referred to *Min. Agric. and Fish.*, Bull. No. 7, "The Scientific Principles of Poultry Feeding."

NOTES ON THE DIGESTIBILITY OF POULTRY FOODS—Table VI. contains data on the chemical composition and digestible nutrients of the foods commonly used in poultry feeding. The starch equivalents given have been obtained in the usual way by multiplying the digestible protein, digestible oil, and digestible carbohydrates by the usual factors, 0·94, 2·3, and 1·0 respectively. The majority of the digestibility figures given are based on digestibility trials carried out in this country and elsewhere on poultry, and consequently differ from the figures usually given, which are based on digestibility trials carried out on ruminants.

The bulk capacity figures are inserted in order that the user may bear in mind the necessity of watching the bulkiness of a ration when constructing it from mixtures of the feeding stuffs here given. An

POULTRY (*Continued*)—

TABLE VI

Chemical Composition of Foods, per Cent., Etc.

	Dry Matter.	*Protein.*	*Oil.*	*Carbohydrates.*	*Fibre.*	*Ash.*	*Digestible Nutrients per Lb. of Food.*		*Bulk Capacity per Oz. of Food in C.c.*
							Protein.	*Starch Equivalent.*	
							Lb.	Lb.	
Alfalfa meal	89·3	14·6	1·8	33·5	31·0	8·4	0·092	0·211	 75
Barley and meal	85·1	8·6	1·5	67·9	4·5	2·6	0·060	0·636	whole .. 43 meal .. 58
Beans and meal	85·7	25·4	1·5	48·5	7·1	3·2	0·203	0·641	cracked 46 meal .. 48
Biscuit meal	90·6	13·9	0·7	74·6	0·3	1·1	0·125	0·840	wet .. 98 dry .. 70
Blood meal	86·0	81·0	0·8	1·5	—	2·7	0·714	0·694	33
Buckwheat	85·9	11·3	2·6	54·8	14·4	2·8	0·069	0·582	whole .. 50 meal .. 45
Buttermilk (dried)	90·0	42·3	11·2	24·3	—	12·2	0·345	0·724	 45
Cabbage	11·0	1·5	0·4	5·9	2·0	1·2	0·011	0·061	— —
Coconut meal	88·7	19·5	6·7	42·5	13·6	6·4	0·142	0·641	 60
Cottonseed meal	91·3	42·1	10·9	24·9	7·4	6·0	0·345	0·683	 47
Dari	88·9	9·6	3·8	71·2	1·9	2·4	0·064	0·782	whole .. 40 meal .. 50
Earthnut meal	89·7	46·8	7·5	23·2	6·4	5·8	0·376	0·684	 46
Fish meal	87·0	55·6	4·4	2·1	—	24·9	0·504	0·571	 43
Groats	92·0	16·4	5·9	66·0	1·9	1·8	0·122	0·838	whole .. 40 meal .. 75
Insects (dried)	85·2	57·6	10·5	—	13·1	4·0	0·397	0·573	—
Maize, and meal	87·0	9·9	4·4	69·2	2·2	1·3	0·079	0·759	whole .. 41 meal .. 49
Maize flaked	89·0	9·8	4·3	72·5	1·5	0·9	0·088	0·853	whole .. 130 meal .. 49
Maize gluten feed	89·6	23·5	3·4	56·7	3·5	2·5	0·200	0·743	 57
Maize gluten meal	90·9	35·5	4·7	47·5	2·1	1·1	0·306	0·815	.. .. —
Meat meal	89·2	72·2	13·2	—	—	3·8	0·557	0·790	 45
Meat and bone meal	90·8	50·5	10·0	5·0	2·2	23·1	0·390	0·592	 45
Millet, bulrush	89·2	12·9	4·7	67·7	1·6	2·3	0·117	0·784	whole .. 37 meal .. 52
Milk, fresh	12·8	3·4	3·9	4·8	—	0·7	0·032	0·162	— —
Milk (dried whole)	95·8	25·5	26·5	37·4	—	6·4	0·240	1·17	 48
Milk (dried skim)	89·8	32·8	0·3	48·8	—	7·9	0·296	0·747	 48
Oats and S.G.O.	86·7	10·3	4·8	58·2	10·3	3·1	0·068	0·567	oats .. 53 S.G.O. .. 74
Pasture grass	20·0	5·3	1·1	8·9	2·6	2·1	0·045	0·136	dry finely ground 100
Peas and meal	86·0	22·5	1·6	53·7	5·4	2·8	0·179	0·656	whole .. 36 meal .. 55
Palm-kernel cake meal	89·0	18·8	7·7	45·3	13·4	3·8	0·132	0·611	 52
Potatoes	23·8	2·1	0·1	19·7	0·9	0·7	0·010	0·176	— —
Rice (whole)	89·8	7·8	2·0	66·7	8·8	4·5	0·058	0·646	 48

POULTRY (*Continued*)—

CHEMICAL COMPOSITION OF FOODS, PER CENT., ETC. (*Continued*).

	Dry Matter.	*Protein.*	*Oil.*	*Carbohydrates.*	*Fibre.*	*Ash.*	*Digestible Nutrients per Lb. of Food.*		*Bulk Capacity per Oz. of Food in C.c.*
							Protein.	*Starch Equivalent.*	
							Lbs.	Lbs.	
Rice (hulled)	87·8	9·1	2·0	74·5	1·1	1·1	0·077	0·842	 35
Rice (polished)	87·6	8·7	0·4	77·4	0·4	0·7	0·069	0·826	 35
Rice meal	91·1	12·9	13·7	49·5	6·4	8·6	0·104	0·839	 45
Rye	86·6	11·5	1·7	69·5	1·9	2·0	0·080	0·676	— —
Soya-bean meal (ext.) ..	88·7	44·7	1·5	31·9	5·1	5·5	0·372	0·634	 52
Sugar-beet pulp (molassed)	93·9	10·0	0·6	64·3	13·6	5·4	0·044	0·204	dry ..112 wet ..250
Ditto (finely ground) ..	,,	,,	,,	,,	,,	,,	,,	,,	dry .. 42 wet .. 95
Sunflower seed cake meal	90·8	36·4	11·0	22·9	14·0	6·5	0·290	0·605	— —
Wheat (" strong " var.) ..	87·9	13·0	2·2	69·6	1·6	1·5	0·114	0·750	whole .. 39 meal .. 50
Wheat (" weak " var.) ..	88·5	9·5	2·0	73·8	1·7	1·5	·084	0·750	whole .. 40 meal .. 47
Wheat bran	87·0	15·1	3·8	52·8	9·5	5·8	0·091	0·336	dry ..185 wet ..140
Wheat midds. (fine) ..	86·8	8·4	2·3	72·7	1·6	1·8	0·064	0·748	dry .. 52 wet .. 50
Wheat midds. (coarse) ..	87·0	16·4	4·4	56·4	6·1	3·7	0·131	0·561	dry .. 79 wet .. 70
Whey (dried)	92·8	13·6	3·0	68·4	—	7·8	0·122	0·846	— —
Yeast (dried)	95·7	48·5	0·5	35·5	0·5	10·7	0·444	0·750	 42

adult bird consumes approximately 290 c.c. of food a day, and the weight of a ration eaten depends largely upon its bulkiness. A ration constructed for any given level of production on the assumption of a daily consumption of 4 ozs. should not, therefore, exceed 73 c.c. per oz. Fibre is one of the factors contributing to the bulkiness of a food, and as a rough working rule the fibre in a ration intended for poultry should not exceed 5 per cent.

From the digestibility trials on poultry carried out at Cambridge by the author, the following facts have emerged:

(1) There appear to be little or no breed differences in digestibility of the same food.

(2) In food of low fibre content, the powers of digestibility shown by the hen are akin to those shown by the pig.

(3) The fibre present in a food affects its digestibility by fowls, foods with high fibre content being less digestible as a general rule than those with a low fibre content.

POULTRY (*Continued*)—

(4) Foods possessing high fibre content are more efficiently digested by pigs and ruminants than by fowls.

(5) Steam cooked foods are more digestible than raw foods, but their economy of use depends entirely on the relative price at which they can be produced as compared with the raw uncooked foods.

E. T. H.

POULTRY MANURE—See Fertilizers.

PRESERVATION—Fruit and Vegetables—The demand for fruit and vegetables out of season has led to the development of industries devoted to the exploitation of methods of preservation. Almost all fruits and many of the vegetables may be preserved by various methods, but those employed commercially are drying or dehydration, bottling, and canning. The advantage of these methods lies in the fact that the fruits and vegetables so treated are preserved in a natural condition, and on being served for consumption are not very much different in appearance from the fresh article. To these three processes must be added a fourth, jam making, but by this method the article under treatment is submitted to processes which change its appearance and result in the evolution of a new product.

For a great many years a large proportion of the fruit crops of Great Britain was converted into jam. When evidence was being taken before the Linlithgow Committee in 1923, it was stated that before the War 90 per cent. of the total raspberry crop, 40 per cent. of the total strawberry crop, and 40 per cent. of the total plum crop was purchased by jam manufacturers every season.

Since the War, the popularity of jam as an article of everyday diet has decreased considerably, and it may safely be stated that at the present time not half of the quantities mentioned above are now disposed of through these channels. The growth of the manufacture of butter substitutes is probably responsible for this state of affairs, as much of the cheaper grade jams was consumed by the poorer classes of the industrial areas. This change in the jam-making industry was in itself sufficient to react adversely on the fruit-growing industry, but the position was intensified by the fact that jam manufacturers have profited by the discovery that fruit can be temporarily preserved in a sulphur dioxide solution, and in such a condition can be purchased at low prices on the Continent and converted into cheap grades of jam at the manufacturer's leisure. This position, however, has been considerably alleviated by the increased consumption of canned fruit, although it must be admitted that the development of the home-canning industry has been marked only during the last two or three years. Prior to this the vast consumption of canned fruit was met mainly by imported supplies, and even granting all the home development possible, the quantities imported will always greatly exceed those produced at home, because of the wider range of fruits the colonial and foreign canning industries are able to offer. Some estimation of the growth in the consumption of canned goods may be formed from the statement in the third report of the Imperial Economic Council that the importation of canned fruit increased six-fold between

PRESERVATION (*Continued*)—

the years 1904 and 1924, and the consumption per head of the population in 1924 was two-and-a-half times as great as that of 1913. About 1925 a concerted step was taken towards the development of the home-canning industry. A National Food Canning Council was set up for this purpose, and was so constituted as to represent fully all the interests involved, including that of the tin-plate industry, which, of course, would reap considerable benefit from such a development. The subject of fruit preservation has engaged the attention of scientific workers at the University of Bristol's Research Station, Chipping Campden, Glos, for some time, and it was appropriate that the setting up of the National Food Canning Council followed the termination of a tour abroad which was undertaken by a member of the Chipping Campden Staff expressly for the purpose of studying the methods of the canning industry abroad.

Before any substantial impetus could be imported to the home canning industry many problems had to be solved. The supply of cans sufficient to cope with the contemplated development had to be organized, and in this connection it was necessary to copy the methods pursued by the American can makers. With the help of up-to-date machinery for can making, imported from America, home production has gradually become more efficient, so that at the present time there is little difference in the cost of cans. Another problem that had to be dealt with was concerned with the lacquering of the inside of the cans. Lacquered cans are necessary owing to the effect of the fruit acids on the tin plate, which brings about bleaching and discolouration of the fruit. But this problem was successfully surmounted with the aid of scientific research, and the fruits canned in English canneries to-day retain their bright attractive colours for an indefinite period.

Again, the intricate machinery necessary to a modern canning plant could not be obtained from English firms of engineers until the latter realized that there was a definite demand for it. This position has been remedied, and all types of automatic canning machinery are now obtainable.

The canning industry, however, could not develop without the cooperation of the grower. But, whereas formerly it was the indifferent fruit of lower grades which could always be disposed of to the jam manufacturer, the canner requires fruit of the best quality, and it is a point of importance that not all the varieties which fulfil the requirements of a general market are suitable for canning. Also, as the fruit required for canning should always be in a good, sound condition, there is much to be said in favour of establishing canning factories in the districts where the fruit is grown.

The following information is now available as to the most suitable varieties of each fruit for canning:

Strawberries—**Sir Joseph Paxton** is the best canning strawberry, with the new variety, **Oberschlesien,** a good second best. **Stirling Castle** is also fairly good.

PRESERVATION (*Continued*)—

Raspberries and Loganberries—**Lloyd George** gives very satisfactory results, followed by **Pynes Royal** and **Semper fidelis.** The one drawback with this and its allied fruit, the loganberry, is that the fruits are liable to contain the raspberry beetle maggot (*Byturus tomentosus*), and careful spraying is necessary to guard against this risk.

Gooseberries—Mature, but green, hard berries of medium size are best for canning, the varieties **Careless Keepsake, Crown Bob,** and **Lancashire Lad** all giving good results.

Black Currants—Large, ripe, but firm and juicy fruits are the most suitable. The varieties **Baldwin, Edina, Victoria,** and **Boskoop-Giant** all give good results.

Plums—Many of the plums can successfully, the best for the purpose being **Victoria, Yellow Egg** or **Pershore, Purple Pershore,** and **Blaisdon Red.** The **Victoria** should be ripe but quite firm, and the others should be on the unripe side but well coloured.

There is no doubt that the substantial advance made by the British canning industry with the assistance of scientific research will be consolidated and continue to grow in importance. It depends, however, and more than is generally realized, on the support and co-operation of the home fruit growers. The latter must realize that the canneries do not, and cannot, exist on fruit of mediocre quality, unsaleable elsewhere; they must, therefore, lay themselves out to produce fruit of the best quality, and of the varieties the canning industry requires. Only with such support will the new industry be able to maintain progress and obtain a share of the enormous market for canned fruit. The fruits mentioned above provide a good field for exploitation, and while it may be possible to add to the list as time goes on, it must be admitted that the English grower cannot hope to get a share of the large trade in canned peaches and apricots, and also pears, as climatic conditions will always rule out these crops.

The trade in canned tomatoes in Great Britain is also very large, but the advantageous conditions attached to the cultivation of this crop in Italy and California are probably against home development.

Although many vegetables may be successfully canned, the only development of note in Great Britain has been in regard to peas, and the pea-canning industry has shown a remarkable expansion during the past two or three years. In the areas where pea growing may be carried on profitably, large contracts are now annually made to supply the canneries.

The peas are generally reaped as they grow and carted to the cannery, where they are then thrashed by special machines which are able to remove the peas from the pods without damaging them. It is also possible to pick the pods in the ordinary way and then shell them by machinery. Peas for canning purposes must be harvested while still immature, as the larger, mature peas tend to become hard and starchy in the can, and consequently lower the quality of the product. The yield of peas tends to vary with the variety, but **Lincoln, Prince of Wales, Alaska, Sangster No. 1, Annonay, Chemin**

PRESERVATION (*Continued*)—

Long No. 4, Yorkshire Hero, Sharpe's First-Early White, Yellow Admiral, and **Green Admiral** are all productive and can well.

The difficulty of securing a bright, well-coloured product which formerly existed with the canned and bottled peas has been surmounted, and a clear, natural green colour is now secured by a simple but quite harmless method.

Other varieties of vegetables which can successfully, and for which a definite future appears to exist, are French beans (the stringless variety), carrots, asparagus, and cauliflower.

The drying industry has not made much headway in Great Britain, although there is an enormous market for dried fruit, notably, however, for dried prunes, apricots, and peaches, which cannot be produced on an economic scale in this country. Dried pears and apples are also imported in large quantities, and although attempts have been made to manufacture "apple rings" from home-grown fruit, apples are generally worth more and command such a ready sale in the fresh condition that, until home production exceeds the consumption, the apple-drying industry is not likely to make much headway. Raspberries are dried in the United States, but this does not appear to have been attempted in Great Britain. Plums have been dried by a few amateurs, but no drying of this fruit takes place on a commercial scale. The dried currant of the grocer's shop is a species of small grape which is cultivated in Greece and Australia, and the raisin and sultana belong to the same class.

To sum up the position, therefore, it seems that the home fruit grower will have to look more and more to the canning industry for future support. The change in the outlook of the jam-making industry has been indicated. Although, no doubt, much home-grown fruit will continue to find its way to the jam factory, there is no doubt that for several reasons the demand will not be constant but decidedly spasmodic. Many of the existing jam-making firms now grow most of the fruit they require, and only in years of scarcity do such firms buy on the open market.

Pickles, Chutneys, and Sauces—An article dealing with the preservation of fruit and vegetables would not be complete without reference to the pickle, chutney, and sauce manufacturing industries. These industries are of importance to the grower, as their products, as in the case of the jam manufacturer, consist for the greater part of the fruit or vegetables which are involved in their manufacture. The pickle trade is the most important to the home grower, as it requires large quantities of onions, cauliflowers, gherkins, walnuts, etc., every year. As in the case of the canning industry, the pickle manufacturers require varieties of vegetables especially suitable for their purpose, and the grower who wishes to make use of this market must keep this point in mind and not expect to find in the pickle trade an outlet for indifferent and unsaleable produce. Most pickle manufacturers are not content to rely for their supplies on the open market, but ensure their requirements by making contracts with

PRESERVATION (*Continued*)—

the growers some time ahead, a fact which should be borne in mind.

The tomato is the principal temperate climate fruit which is utilized by the sauce and chutney manufacturers. Although the bulk of the fruit so utilized is imported, there appears to be no special reason why this market should not be developed to the advantages of the home grower in the future. It is fair to state, however, that the bulk of the tomatoes used by these industries are the product of the open fields and not glasshouse grown, an important factor in production costs.

PRESSES—Various types of press have been used on farms, and are used to-day, for different purposes. The considerations involved in the choice of a press are twofold: (*a*) What happens when the pressure plate reaches the extremity of its traverse on the pressure side; and (*b*) what happens when the pressure is put on and the press left to itself. The first is a matter of design, the second may often be varied with the practical end in view.

In the old dead weight press, the pressure was exercised by a heavy weight placed on top of the object to be compressed, and it is clear that the pressure remained constant throughout the traverse of the pressure plate, and *ipso facto* also remained so when the press was left to itself.

In spring presses the pressure is imparted by the compression of a strong spring. If no arrangement is provided to obviate the fault, such presses are not able to exert their maximum pressure when the pressure plate is near the extremity of its traverse, and owing to the gradual extension of the spring the pressure exerted becomes gradually lessened as it takes effect.

The screw press pure and simple is familiar to all in the common office press used for copying letters. Such a press is capable of exerting its maximum pressure at any point of the traverse of the pressure plate, but is only suitable for use with things which compress very easily or with great difficulty. If the compression is easy the whole process may be completed while the operator remains at the press turning the screw to keep up the pressure. If the object to be subjected to pressure is hardly capable of compression, as for example a letter book, the press may again be used, as once the pressure is applied the object will not flatten out sufficiently to reduce it to too great an extent.

In pressing cheese it is important that the pressure should remain constant throughout the pressing, and it is also of considerable advantage to be able to compute what the pressure is and to vary this at will. These desiderata are secured in the compound lever cheese press illustrated in Fig. 19. The pressure plate is pushed downward by a screw which passes through a collar in the lever A, the distance between the pressure plate and the collar being variable by means of the rotary sleeve *w*. The pressure is applied by weights hanging at B from the end of the lever L.

The computation of the force applied proceeds as follows: If *ab*

PRESSES (*Continued*)—

represent the distance between the points designated by a and b respectively, and so on for other letter combinations, and if the weight at B is m lbs., then the downward pressure at a is $2\ m$ lbs. because of the pulley. That at c and therefore at d is $2\ m.\frac{ab}{bc}$ lbs., and hence that at f and therefore on the pressure plate is $2m.\frac{ab}{bc}.\frac{de}{ef}$ lbs. Dividing this by the area of the pressure plate in square inches, we obtain at once the pressure applied in pounds per square inch, neglecting the weights of the levers and screw. The so-called gang cheese presses in which several cheeses are pressed at the same time are operated on very much the same principle: the cheeses are placed horizontally, and the pressure levers are cranked.

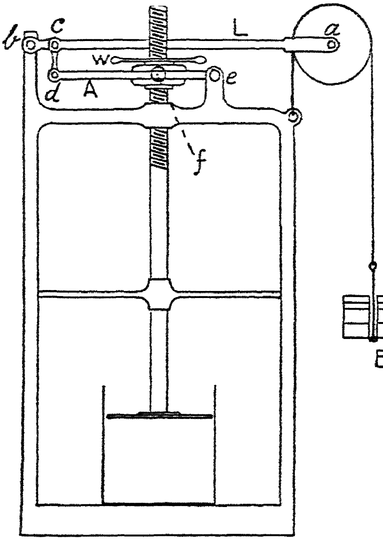

FIG. 19.—CHEESE PRESS (COMPOUND LEVER TYPE).

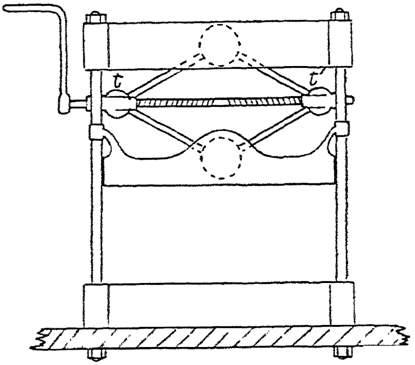

FIG. 20.—TOGGLE CIDER PRESS.

Fig. 20 shows a type of press used in the making of cider and in other cases where it is desirable that the pressure should increase as the pressing proceeds. It is called a toggle press, being operated by two toggle joints, *tt′*, which, as they are drawn together by the rotation of the right and left handed screw, exercise an ever-increasing downward pressure on the pressure plate. In this way a light pressure is applied at first when the fruit mass is full of juice, while the last drops are expelled under very great compression with little or no extra effort expended in turning the handle.

A useful press for general purposes is the hydraulic press sketched in Fig. 21. Its action depends on the fact that liquids transmit pressures equally in all directions. A force pump, P, is used to force water or oil from the reservoir R to the pressure chamber C, which is completely filled with the liquid and closed by means of the ram M and a hydraulic

PRESSES (*Continued*)—

washer hh'. If the effective pressure on the piston of the pump is x lbs. per square inch of piston, this will be transmitted by the liquid as a pressure of x lbs. per square inch on the walls and sides of the pressure chamber, and on the sides and bottom of the ram. Hence the total upward pressure on the ram will be:

$$x \times \frac{\text{area of base of ram}}{\text{area of piston}} \text{ lbs.}$$

The pressure attainable with such a press is limited only by the power available in the pump, the bursting pressure of the chamber and pump cylinder, and the breaking tension of the uprights.

When it is desired to release the pressure it is only necessary to open a release cock providing communication between the chamber and the reservoir, when the pressure forces liquid back into the reservoir and the ram falls. Within the limits of the power available, the pressure obtainable depends on the resistance encountered at all points in the traverse of the pressure plate, a maximum resistance at any point immediately calling forth the maximum pressure.

T. D.

Fig. 21.—Hydraulic Press.

PROTEINS—The solid matter of the cytoplasm of living cells is composed almost entirely of proteins. Proteins therefore form the basis of all living things. In animal tissues they make up the greater part, and in lean meat as much as about four-fifths of the dry matter. In plants they are present in a much lesser degree. They are much more abundant in the young growing tissues than in the framework supporting structures. Leguminous herbage is generally richer in proteins than is the case in other plants. The writer has found about 30 per cent. in the very young leaves of wild white clover, whereas very young growths of perennial rye-grass contained about 20 per cent. As the herbage grows older its protein content falls. Milk and seeds are rich in proteins.

Owing to the intimate associations of proteins with the life of plants and animals they have always attracted the attention of the chemist. It has long been known that albumin-like substances, first named "albuminoids," could be extracted by various means from many materials of animal or vegetable origin. For example, casein, which

PROTEINS (*Continued*)—

separates when milk is curdled; fibrin, when the clotting of blood takes place; and gluten, which remains when the starch is washed away by water from wheaten flour. It was found that these substances all had features in common. For instance: their elementary composition was approximately the same, namely, carbon about 52 per cent., hydrogen about 7 per cent., nitrogen about 16 per cent., oxygen about 24 per cent., and sulphur about 1 per cent.; they resembled one another in their physical properties, and gave much the same chemical tests; they were converted by the ferments of the digestive juices into "peptones," which showed all the known characters of the parent proteins with the exception that they were very soluble in water.

These facts gave rise to the view that the proteins formed a group of substances of close chemical similarity.

Until comparatively recent times the accepted view as to the digestion and utilization of proteins by the animal was that they were converted by the ferments of the digestive juices into soluble proteins or "peptones," and that, as such, they were absorbed from the intestines into the blood stream by which they were conveyed to the various tissues, where they were utilized as structural material in repair or growth.

Holding this view, there was no particular reason why all proteins should not have exactly the same nutrient value to the animal. Whilst there is no record of insistence upon this point, yet it was tacitly assumed. For instance, in the literature dealing with feeding standards a certain quantity of protein is stated to be required with no reservation as to its nature. Again, in all the analytical data for feeding stuffs upon which calculations of rations for animals according to the starch equivalent method are based, the percentages of proteins are given with no remarks as to their nature.

With the progress in the study of physiological chemistry our knowledge of the make-up of the foodstuffs, and of the significance of the processes to which they are subjected in the alimentary tract, has been very greatly augmented. Instead of the original conception of digestion as a simple act of solution we must now regard it as involving intricate and delicately regulated chemical transformations. Amongst these developments a flood of light has been thrown upon the chemical structure and physiological behaviour of the proteins.

The elementary percentage composition of a compound is no criterion of its molecular structure, but it does afford the means of calculating the lowest figure which could represent the molecular weight. On applying such a calculation in the case of a protein an extremely large minimum figure results. It is evident therefore that, relatively, protein molecules are of huge size and their molecular structure extraordinarily complex. To determine precisely the arrangement of the constituent atoms in so complicated a molecule is a problem of almost insuperable difficulty, and views as to the constitution of proteins depend very largely upon deductions based on the nature and yield of the products of their breakdown.

The two chief methods of breakdown which have been employed

PROTEINS (*Continued*)—

are: (*a*) the proteins have been boiled for many hours with diluted hydrochloric and sulphuric acids, and (*b*) they have been subjected to the prolonged action of the ferments of the digestive juices under conditions agreeing as closely as possible with those which occur in the alimentary tract. With two or three exceptions of products which are given by method (*b*) but decomposed in method (*a*), these two methods, if allowed to operate for sufficient lengths of time in the case of any one protein, yield the same final products in the same quantitative relationship. Further, studies of the intermediate phases suggest that the order of breakdown is the same in both cases.

The final products are crystalline nitrogenous substances called amino acids. Eighteen are now definitely known. Although, compared with the parent protein or its " peptone," these are very simple substances, which individually are easy to obtain from their solutions in the crystalline form, yet they all exhibit a characteristic feature rendering isolations from the breakdown mixture a matter of the utmost difficulty, namely, they behave as acids in the presence of bases and as bases in the presence of acids. They therefore form more or less loose complex salt-like unions with one another, and crystal fractions obtained from the mixture are also mixtures. Consequently fractional crystallization, one of the mainstays of the organic chemist, is of no avail in attempting to separate them.

The amino acids are of three types: (1) those capable of combining with one equivalent of acid and one equivalent of base; (2) with one equivalent of acid and two equivalents of base (the " dibasic amino acids," see below); and (3) with two equivalents of acid and one equivalent of base.

The complete separation of these substances from one another was practically a hopeless task until Fischer, in 1901, converted them together into a certain type of product of volatile nature called an " ester " and devised a method for the fractional distillation of these " esters." On reconverting the various fractions into amino acids he was then able to isolate and identify several of them and also to estimate their approximate content in the protein under investigation. Chiefly by the aid of this method, it was found possible to account for about two-fifths of the weight of a protein in the combined yields of the then known amino acids.

Since then great progress has been made. The Fischer-method was thoroughly tested by various workers, and new ways of preparing the " esters " in improved yield were introduced by Levene and Van Slyke in 1909, and Foreman in 1913. Each of these methods in their turn considerably raised the sum of the percentages of known amino acids in various proteins, so that by 1914 in some cases as much as 80 per cent. of the weight of a protein could be accounted for.

In 1914, Foreman introduced a precipitation method whereby the whole group of " dibasic amino acids " are quantitatively removed from the other breakdown products. This method gave very greatly increased yields of the known dibasic amino acids in every protein reinvestigated, greatly simplified the problem of dealing with the remain-

PROTEINS (*Continued*)—

ing amino acids, and " led directly to the discovery of hydroxyglutamic acid in casein by Dakin in 1918 " (Vickery, " Recent Advances in Protein Chemistry," 1924). Chiefly by the aid of this method Dakin was able to increase the total of amino acids accounted for in gelatin up to 91·3 per cent., and in zein, the chief protein of maize, up to 101·5 per cent.

In the meantime chemists have been tackling the difficulties of separating the proteins in a higher state of purity from various organic materials including agricultural produce. The vegetative parts of plants prove to be the most intractable material, especially in regard to obtaining the proteins in satisfactory quantities, but even in this direction considerable progress has been made recently.

The methods outlined have been applied to many proteins. The percentages of the various amino acids isolated in the case of some of those which are of agricultural interest, calculated on the basis of the weight of dry protein taken, are given in the following table. For present purposes the amino acids may be regarded simply as the units of which the proteins are built up, and an explanation of their chemical structure is not necessary.

The complete investigation of a protein is a very arduous undertaking occupying several months, and, obviously, a considerable time must elapse before the latest methods are applied to proteins in general. The more satisfactory results given in the table for casein and gelatin show what can now be achieved. Most of the other analyses are much older and show a much larger deficit. The figures for arginine, lysin, and histidine, however, are generally regarded as fairly accurate, and the other figures, although somewhat low, represent similar proportions of the actual amounts, so that comparisons sufficiently satisfactory for present purposes may be made. These results show clearly that the proteins which were so long regarded as chemically similar and of equal feeding value are really very diverse in structure.

It is seen that the animal proteins differ markedly from the plant proteins, but differ among themselves less widely than the plant proteins. The figures given for the pea protein broadly resemble those available for the proteins of several other leguminous seeds. The proteins of the cereal grains (including maize) differ very widely from the other plant proteins, especially the leguminous seed proteins, and still more widely from the animal proteins, in yielding very much smaller quantities of arginine and lysine and very much larger quantities of proline and glutamic acid.

Although each known amino acid has been found in many proteins, yet in some cases one or more may be absent. For example, egg-albumin and the gliadin of wheat give no glycine; casein practically no cystine; the hordein of barley no glycine or lysine; the zein of maize no glycine, tryptophan, or lysine; and in the case of gelatin no less than six of the amino acids are missing, namely, valine, isoleucine, tyrosine, cystine, hydroxyglutamic acid, and tryptophan.

After it was known that proteins were split into amino acids by the ferments in the digestive juices, biochemists for a long time failed to

PROTEINS (*Continued*)—

PERCENTAGES OF AMINO ACIDS

Animal Proteins.

Amino Acids.	*Egg Albumin.*	*Fibrin from Blood.*	*Casein from Milk (Cow).*	*Ox Muscle Protein (tissue protein).*	*Gelatin (Connective tissue protein).*
Glycine	0	3·0	0·45	2·1	25·5
Alanine	2·2	3·6	1·85	3·7	8·7
Valine	2·5	1·0	7·93	0·8	0
Leucine	10·7	15·0	9·7	11·7	7·1
Isoleucine	....	....		....	0
Phenylalanine ..	5·1	2·5	3·88	3·2	1·4
Tyrosine	1·8	3·5	4·5	2·2	0
Serine	....	0·8	0·5	....	0·4
Cystine	0·4	1·2	0 (?0·1)	....	0
Proline	3·6	3·6	7·63	5·8	9·5
Hydroxyproline ..	....	....	0·23	....	14·1
Aspartic acid ..	2·2	2·0	4·1	4·5	3·4
Glutamic acid ..	9·1	10·4	21·77	15·5	5·8
Hydroxyglutamic acid	....	....	10·5	....	0
Tryptophan ..	+	1·3	1·5	+	0
Arginine	4·9	....	3·81	7·5	8·2
Lysine	3·8	....	7·62	7·6	5·9
Histidine	1·7	....	2·5	1·8	0·9
(Ammonia) ..	1·3	....	1·6	1·1	0·4
Total ..	49·3	47·9	90·07	67·5	91·3
	(Osborne Jones and Leavenworth.)	(Chiefly Abderhalden.)	(Foreman; Osborne and Guest; Dakin.)	(Osborne and Jones.)	(Dakin.)

+ = certainly present but in unknown amount. 0 = certainly absent.

SEPARATED FROM PROTEINS

Plant Proteins.

Wheat Protein, "Gliadin."	*Maize Protein, "Zein."*	*Barley Protein, "Hordein."*	*Pea Protein, "Legumin."*	*Cotton Seed Protein, "Edestin."*	*Protein from Linseed.*	*Protein from Swede Turnip.*
0	0	0	0·4	1·2	+	0·27
2·0	9·8	0·4	2·1	4·5	1·1	3·58
3·4	1·9	0·2	....	+	12·7	9·95
6·6	19·6	5·7	8·0	15·5	4·0	9·01
....	....	....	....	....		
2·4	6·6	5·0	3·8	3·9	4·2	4·47
1·2	3·6	1·7	1·6	2·3	0·7	2·92
0·2	1·0	....	0·5	0·4	+	....
0·5	....	....	....	....	....	+
13·2	9·0	13·7	3·2	2·3	2·9	4·17
....	....	....	....	....	....	....
0·6	1·7	....	5·3	2·9	1·7	6·98
43·7	26·2	36·4	17·0	17·2	11·6	3·18
....	....	....	....	....	....	....
1·0	0	+	+	+	+	+
3·2	1·6	2·2	11·7	....	6·1	3·12
0·2	0	0	5·0	....	1·2	4·35
0·6	0·8	1·3	2·4	....	1·7	3·04
5·2	3·6	4·9	2·1	....	1·9	1·21
84·0	85·4	71·5	63·1	50·2	49·8	56·25
(Osborne and Guest.)	(Osborne and Liddle.)	(Osborne and Clapp.)	(Osborne Clapp and Heyl.)	(Abderhalden and Rostoski.)	(Foreman.)	(Williams, with Foreman.)

= presence or absence not yet determined.

PROTEINS (*Continued*)—

demonstrate the actual absorption of amino acids into the blood. When, however, the Van Slyke method, which accurately estimates minute quantities of amino acids in fluids such as the blood, was introduced, progress was rapid, and the following facts were satisfactorily established: (1) that amino acids were constantly circulating in the blood, (2) their content in the blood increased during the period a meal was in process of digestion, (3) they were taken up by the tissues so rapidly that they never accumulated in the blood in quantity sufficient for actual isolation.

It is evident therefore that amino acids are actually absorbed as such from the intestines into the blood and that the body cells remove and utilize them. That this is so is also shown by the results of feeding experiments in which certain animals grew well and kept healthy, when the proteins of a diet which previously proved satisfactory were completely replaced by the mixture of amino acids which these quantities of proteins gave when completely broken down. Proteins as such were therefore not essential in the diet.

The fate of the amino acids on elimination from the blood is at first a little unexpected, for the greater part of their nitrogen appears in the urine in the form of urea, and the deaminated residues go to supply energy. At first sight, therefore, it would appear that animals, like plants, can synthesize from simpler compounds the amino acids required for building up their body proteins. It has been shown, however, that a certain few of the amino acids cannot be synthesized in the body, namely, tryptophan, cystine, lysine, histidine, and possibly arginine, tyrosine, phenylalanine, and proline. The animal therefore depends upon the proteins of its diet for these " special units " (Jordan Lloyd, " Chemistry of the Proteins," London, J. and A. Churchill, 1926), and the feeding qualities of a protein may be gauged according to its content in them.

A full account of the evidence upon which these findings are based cannot be given in so short a paper. A few typical experiments may be briefly referred to, however, for illustration.

Willcock and Hopkins, in Cambridge, found that mice were unable to subsist on a diet in which the zein of maize was the only protein. As stated, zein contains neither tryptophan nor lysine. On adding tryptophan to the diet the mice remained healthy for a very much longer time, and on the addition of lysine as well as tryptophan the experimental animals were as good as the controls.

Osborne and Mendel, in America, obtained similar results on the addition of cystine to the diet when the only protein there was casein, which contains practically none of this amino acid.

It has been recognized for a very long time that gelatin is an unsatisfactory protein foodstuff. As stated, it is now known to be devoid of no less than six of the amino acids, amongst which are three "special units," namely, tryptophan, cystine, and tyrosine.

Such experiments show that the most important function of proteins in the diets of animals is to supply certain " special amino acid units," which the body is incapable of synthesizing, to serve as structural

PROTEINS (*Continued*)—

material in the repair or growth of tissue. It is important to note, however, that not only must the special units be present, but they must also be available. The proteins must, therefore, be digestible.

It is evident that the value of a protein in a diet depends upon its constituent amino acids and upon its digestibility. Attempts have been made to assign to proteins figure values representing their respective "biological values," as determined in feeding experiments, but animals generally receive more than one protein, and it is obvious that the amino acid deficiencies of one may be supplied by another or others. The biological values would therefore vary according to the circumstances. Thus, two proteins which might both be classed as poor may yield a satisfactory amino acid mixture when digested together. For example, it has been shown that gelatin, of little or no value as the sole protein constituent in a diet, may supplement the feeding value of the protein of the oat. Also, when gelatin was added to wheat gliadin in a diet given to young rats, there was immediate growth. Whereas when gliadin was the only protein there, the rats kept at steady weight showing there was no growth, and in the case of gelatin as the only protein they could not even maintain their weight.

It follows that the more numerous the proteins contained in a diet, the less likely is it to give an inadequate supply of the "special units," and the more satisfactory the feeding results.

Even the limited data given in the table will serve to illustrate the important practical suggestions which may be made. It is evident that several of these proteins are complementary to one another in their amino acid contents, leading to the appropriate suggestions in the rationing of animals. For example, cereal grain products might be supplemented in the ration by leguminous seed products, or meat meal, or fish meal, or milk, or the swede turnip, in order to provide more of the important "special units," tryptophane, arginine, lysine, and histidine, and to tone down the obvious excesses of proline and glutamic acid.

Suggestions have been made in the past that each species of animal requires the amino acids arising from the proteins in its diet to be in the same proportion as in its tissue proteins. These suggestions were founded chiefly on the results of a series of experiments in which dogs were shown to maintain their weight on far less protein supplied as dog flesh than when supplied in other forms. According to present views, whatever truth there is in the suggestion applies more particularly in the case of the "special units," which the animal is unable to synthesize. It is perhaps remarkable that the amino acid percentages given in the table for ox muscle protein differ only a very little from those which are available for the muscle proteins of the chicken and the halibut.

It is evident that the quantity of protein needed by an animal will be that quantity which supplies enough of the "special unit" which is most deficient in relation to the animal's needs. If this deficiency is great this quantity of protein will supply some of the other amino acids, including other "special units" in large excess above the animal's

PROTEINS (*Continued*)—

requirements. It is true that the amino acids thus in excess would be available as a source of energy, but since much less protein would be necessary if the "special unit" supply were satisfactory, this energy could be supplied from much cheaper sources, *e.g.*, carbohydrate, and there would therefore be waste in the sense that the animal is not making the fullest use of the various "special units" as structural material in the repair or growth of tissue. Although animals tolerate considerable fluctuation in the protein concentration of their diets, yet when too much protein is ingested, ill-health results. Osborne and Mendel give 30 per cent. as a dangerous figure. On the other hand, they showed that young rats grew satisfactorily when the diet contained as little as 4½ per cent. of protein in the form of lactalbumin, which obviously was very suitable in supplying "special units" in favourable proportions for the rat. Health in the animal and economy in animal production are intimately related.

In the foregoing pages an attempt has been made to indicate, in the study of this one special factor in an animal's diet, the lines along which the science of animal nutrition is advancing. Every protein has its own particular structure and its own feeding value, and "in calculating a scientific basis for diet the 'percentage of protein' is a value which has very little meaning" (Jordan Lloyd, *loc. cit.*). It should, therefore, be regarded as essential to take into account the animal's requirements in relation to the structure of the proteins in its diet.

F. W. F.

PUMPS—These are used on the farm chiefly for raising water either from a well to ground level or for pumping it up to high-level tanks. The simplest type is the ordinary farmyard lift pump illustrated in Fig. 22. Let GG′ be the ground level and WW′ the well-water level. When the handle *h* is raised and depressed again water is drawn up into the well pipe *t* through the rose filter R, and passing through the valve *v* enters the space above this. When the handle is again raised, the water in this space cannot pass down again through *v*, but when the plunger P comes in contact with it, the pressure on the plunger forces the water through the upper valve *v′* in the plunger. On again depressing *h*, the process is repeated, and so water gradually accumulates above *v′* until it pours out at the end of each stroke by way of the spout *s*. The guide *g* enables the plunger rod *l* to move vertically up and down despite the slight angle to the vertical at which the force is applied by the handle *h*, which is usually so fixed as to pull vertically at half stroke. A pump of this type is useless for raising water from a greater depth than 30 ft., since no amount of priming will then permit of water being drawn into the space above *v*. Even if a complete vacuum could be produced in *t*, this would still be impossible above 34 ft., since this is the height of the water barometer.

When water is to be raised to a greater height than this, something of the nature of a *force pump* must be used. The variety in details of construction of these pumps is very great; fire pumps, wind pumps, and many rotary and semi-rotary pumps are built on this principle.

PUMPS (*Continued*)—

It seems desirable, therefore, to illustrate this by a diagram a little more divorced from the practical side. In Fig. 23 the general principle of the force pump is illustrated. The plunger P, on moving upwards, draws water from the supply pipe *t* into the space above the valve *v*, then on the downstroke of P this water is forced by the pipe *t'* through the valve *v'* into A, which is an air chamber. During the subsequent upstroke of P, the pressure in A keeps the valve *v'* shut, and forces the water up through *t''* to wherever it is required. The air chamber

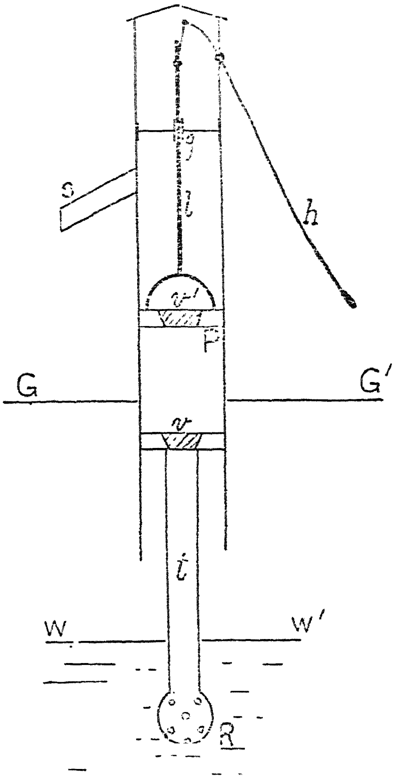

FIG. 22.—LIFT PUMP.

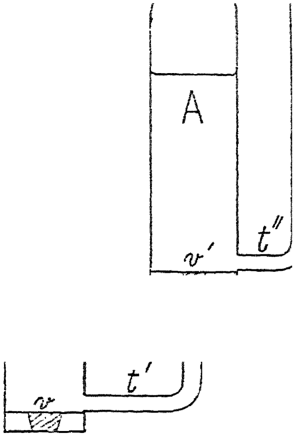

FIG. 23.—PRINCIPLE OF FORCE PUMP.

then serves to maintain a continuous flow up the pipe *t''*; without it this flow would naturally be intermittent. The height to which the water may be raised by a force pump is dependent only on the power available at P. The differences between the types of force pump employed in practice will be found to reside principally in the situation and design of the valves and air chamber, and where an intermittent flow is not detrimental, this latter may be omitted altogether. In the wind pumps, for example, which are now such a characteristic

PUMPS (*Continued*)—

feature of the British countryside, a valve is situated in P as in the lift pump, while a third valve at the top of the cylinder gives access to the delivery pipe and an air chamber is omitted; while in the ordinary semi-rotary hand pump the valve system is duplicated on either side. In all these cases the reader will have little difficulty in seeing the application of the principle embodied in Fig. 23, when the particular pump he is considering is partially dismantled.

Where it is desired to raise large volumes of water rapidly, and the pump is to be power driven, a pump of the double-acting type may be considered either with or without an air chamber, and with or without a three-throw action; in the latter case an air chamber is unnecessary. Double-acting pumps are made both in lift and force pumps, and they have the advantage that the return stroke of the piston is as useful as the power stroke. The mode of action of one form of double-acting force pump is illustrated diagrammatically in Fig. 24.

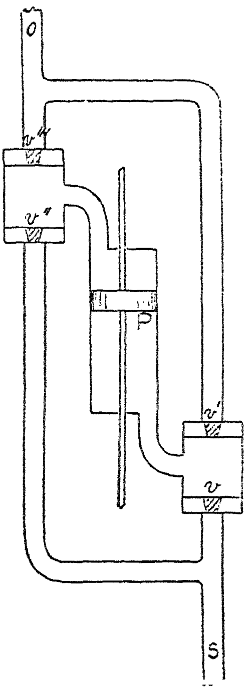

Fig. 24.—Double-Acting Force Pump.

Consider what happens when the whole apparatus is full of water and P is moving upwards. Water will be drawn through *v* and forced through *v'''*. What passes through *v* will pass to the part of the cylinder below P, since both the pressure forcing water through *v'''* and the reduction of pressure below *v'* tends to keep *v'* shut, and since *v'* is shut, the whole of the water passing *v'''* must pass up the pipe *o*. If now the piston P reaches the top of its stroke and begins to descend, the water pressure from above and the suction from the piston will close *v'''*, the force from the piston will close *v* and open *v'*, while the suction from above will open *v''*. Thus water will now pass through *v''* and through *v'*, and that which is forced through *v'*, since it cannot return by *v'''*, which is now closed, must also pass up the pipe *o*. Hence, water is continuously being drawn from the supply pipes and forced out through the delivery pipe *o*. When three such arrangements are worked in parallel from a crank shaft with the pistons set at 120° phase difference, a remarkably effective pumping arrangement results.

It is of importance to remember, however, that there is such a thing as a friction of liquids in pipes, and that to have the delivery pipe cross-section equal to only a very small fraction of the piston area results in such a rapid flow of water in the delivery pipe that extra power has to be supplied to overcome what is called the "friction-head." Another even more important point for consideration in the selection of a force pump is expenditure of power due to the starting

PUMPS *(Continued)*—

and stopping of the upward motion of a long column of water. This is very great, and is, moreover, a strain on the machinery of the pump in extreme cases, so that where it is a question of raising water to a considerable height, or in quick-running pumps, either a three-throw pump or one fitted with an efficient air-chamber should always be selected.

It remains to add a word about centrifugal pumps. These machines are the precise reverse of turbines. In the latter, water moving at a great velocity is allowed to impinge on vanes fixed on an axle inside a casing in such a manner that the water is directed from the circumference to the centre and there allowed to flow away. In this way the kinetic energy of the rapidly moving water stream is able to be converted into mechanical work. By reversing the process and leading water in to the centre of the vanes while driving these at a great speed in the opposite direction, water may be forced to ascend what in the previous case was the supply pipe. Such an arrangement is known as a centrifugal pump, and in such instruments it will be clear that the water is as it were *thrown* up the delivery pipe; hence the more rapidly the vanes are rotated the greater the height to which the water can be pumped.

T. D.

QUARTZ (Rock crystal, SiO_2)—A mineral occurring in most countries to some extent. It crystallizes in the hexagonal system, and is of hardness 7 on Mohs' scale. The completely transparent rock crystal is used for making spectacle lenses; other coloured varieties are known as milk quartz, false topaz, amethyst, chalcedony, jasper, and agate. Fused quartz is used in laboratories in the form of "silica vessels," which are resistant to sudden and extreme temperature changes, while quartz fibre, made by shooting arrows, the back of which is attached to some of the molten mineral, to great distances, is used in many physical instruments of precision.

RADISH—See Market Gardening.

RAM, HYDRAULIC—This furnishes a convenient means of raising water to a height considerably above the source, under conditions where the supply is unlimited and, therefore, waste of water does not matter. A pipe of large dimensions is carried from the source to the ram, which is situated at a somewhat lower level. At the ram, this pipe is provided with two valves: a waste valve opening inwards, and of such a size as to allow the water to flow down the pipe at a good pace and out into a stream, and a delivery valve opening into an air chamber, when the pressure inside the pipe becomes sufficiently great. Water, therefore, rushes down the pipe until its velocity is great enough to shut the waste valve, whereupon an enormous pressure is produced at the ram end of the pipe, owing to the sudden blocking of the outlet and the fact that the whole of the water in the pipe was previously in motion towards the ram. This pressure is sufficient to force open the delivery valve, and water rushes into the air chamber, whence it may be carried to a height considerably exceeding that of the source.

RAM, HYDRAULIC (*Continued*)—

When the pressure becomes reduced again the waste valve opens, either by its own weight or by a subsidiary spring when the elevation of the source is small; if the source is considerably above the ram, the final internal pressure in the pipe must be released by a subsidiary valve, which may be operated by a trigger mechanism from the air chamber or otherwise. The ram then continues in operation until stopped. The energy for the raising of part of the water to a great height is derived from the kinetic energy acquired by the water in the pipe at the moment that the waste valve closes.

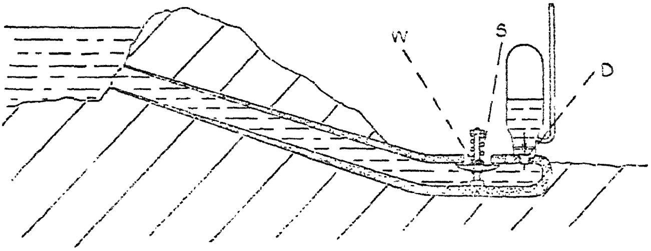

FIG. 25.—HYDRAULIC RAM BUILT INTO RIVER BANK AND CONSTRUCTED FOR HIGH LIFT.

Fig. 25 shows a hydraulic ram built into a river bank, the supply pipe being concreted on the outside to withstand the considerable strain to which it is subjected. The waste valve W is shown at the moment of closing, the delivery valve D just opening and the air chamber filling with water. The strength of the spring waste valve control S must be sufficiently great to overcome the total upward pressure on the bottom of the waste valve due to the head of water from the river surface, but it is assisted in this by the weight of the valve itself to such an extent that, as has been stated, a spring is often unnecessary.

The efficiency of hydraulic rams falls off as the height to which the water is to be raised is increased. When this is ten times the head from the source of the ram the efficiency may be about 50 per cent.

T. D.

RAPE CAKE—For composition, feeding and manurial values, see Feeding Stuffs; for value as a manure see Fertilizers.

RAPE OR COLE SEED—Rape, or cole seed as it is more generally called in the eastern counties of England, is one of the most valuable forage crops.

Its wide adaptability to varying conditions of soil and climate, the ease and cheapness with which it can be grown, its comparative

RAPE OR COLE SEED (*Continued*)—

immunity to pests and disease, and its high feeding value, for sheep in particular, are highly desirable characteristics.

Rape may be grown either as a main crop or as a catch crop. When grown as a main crop, methods of cultivation, seeding, manuring, etc., are identical with those recommended for marrow-stem kale (*q.v.*). It is grown, however, more often as a catch crop to provide sheep-keep in autumn and winter. If sown in April it is ready for folding by August, and this is the principal use to which rape is put when grown as a main crop.

Rape, next to mustard, is the most popular catch crop and is used to follow early potatoes, early or picking peas, or for sowing on a bastard or bare fallow.

When used as a catch crop the cultivations and manuring given are usually very limited. The cultivations which have been given to the previous crop, *e.g.*, early potatoes, make an ideal preparation, and the seed bed may be prepared by one harrowing and rolling. Where rape follows peas the land must be ploughed and then harrowed down to a fine tilth. The ease with which rape can be grown makes farmers rather indifferent on the score of making any great attempt at producing an ideal seed bed.

The two principal varieties are **Giant** and **Essex Dwarf**, and of these there are several strains. The Dwarf types are best suited for fen and other soils of high humus content, and the Giant types for the poorer and lighter kinds of land. (See Brassicæ, Morphology and Genetics of.)

It is not usual to apply any artificial manure where rape is grown as a catch crop, but when any is used it is usually a nitrogenous fertilizer such as sulphate of ammonia and nitrate of soda, at the rate of 1 to 1½ cwts. per acre.

Sowing is invariably done on the flat and not on ridges or balks. The seed may be drilled or broadcast, but the latter is the much more common practice. When drilled, 4 to 5 lbs. per acre of seed is required, and 10 to 12 lbs. per acre if broadcast.

Frequently, rape is sown in conjunction with a mustard, half-and-half seeding being usual.

No cleaning operations are given after seeding, and, indeed, these would be impossible where the seed has been broadcast. Once the crop is established it has, by reason of the large leaf development, an excellent smothering effect on weeds, and prevents them seeding.

Sown in this way rape will provide an abundance of sheep-keep throughout the winter, or, if required for green manuring, a suitable quantity of green stuff will have been produced for ploughing under in preparation for winter corn.

Another use to which rape is frequently put is that of a cover or nurse crop for grass and clover seeds. For this purpose the rape seed is broadcast with the grass and clover seeds, either in spring or late summer. Subsequently, the rape is not folded, but grazed off lightly, to avoid damage to the grass and clover seedlings.

In feeding off rape, care should be taken that sheep do not eat too

RAPE OR COLE SEED (*Continued*)—
much of it when first turned in, or they may get "blown" or "hoven." Sheep should not be turned in in a fasting condition, or when the leaves are wet, but should be put on the crop for an hour or so at first, and the length of time increased gradually each day until they can be left safely for the whole of the day. Where hay is available it is advisable to feed a little along with the rape, as this will tend to mitigate some of the harmful results that may accrue from over-consumption of a succulent food.

An average crop of rape will produce about 15 tons of green food per acre or the equivalent of 21 cwts. starch per acre. Comparing this figure with the 19 cwts. of starch equivalent per acre, which is the average yield of swedes, the value of rape as a source of green food for sheep will be readily appreciated.
J. C. L.

RASPBERRY—See Soft Fruits, under Fruit.

RATS AND MICE—In recent years there has been a wider realization than ever before of the injury done by rats and mice to man and the products of his labour. Rats and mice are a twofold menace: not only do they do enormous damage by consuming and destroying food supplies of every description, and by extensive damage to buildings and so forth, but they act as intermediaries in the distribution of disease. The Great War produced visible signs of their appalling destructiveness, but the invisible danger they and their parasites are causing is even yet not fully established or realized.

It has been estimated by Kuhnhardt that various forms of plague, largely distributed by rats, cost India during a period of twenty years the enormous sum of 828 millions sterling. On the Continent, trichinosis, a disease caused by a parasitic worm, is a common malady extended through the agency of rats. Infective jaundice and rat-bite fever are definitely caused through the agency of rats, and psittacosis (parrot disease) is considered by some authorities to be due to a non-filterable virus common to rats and mice, which are also suspected of being the carriers of other diseases communicable to human beings and domestic animals. Research may confirm these suspicions and perhaps add more indictments of these pests. One need scarcely enlarge upon the extensive damage done to farm products by rats and mice; the loss of stored crops, young chickens, etc., and the damage done to farm buildings are visible to all who have eyes to see.

There are two species of rats found in Great Britain, the Brown Rat (*Rattus norvegicus*) and the Black Rat (*Rattus rattus*). The former, also known as the field, sewer, or Hanoverian rat, frequently lives in close proximity to waterways, and is often called a water rat, sometimes being confused with our indigenous water vole (*Arvicola amphibius*), a comparatively harmless animal; a melanistic variety of the brown rat is found in Ireland and is named *Rattus hibernicus*. The black rat is strongly entrenched in certain districts, particularly in cities, together with a variety named *Rattus alexandrinus*.

The common House Mouse (*Mus musculus*) is ubiquitous in Great

RATS AND MICE (*Continued*)—

Britain, and is liable to occur in immense numbers in corn stacks which are left long unthrashed, or in association with stored grain where due care is not exercised.

All these rodents are of alien origin. The house mouse was probably introduced into England several thousand years ago by the Phœnicians, who came to Cornwall in their quest for tin. Rats are of more recent appearance in this country, and it is believed that the Crusaders were the cause of the black rat reaching England. As so often happens when a new species is introduced into a fresh and suitable environment, the black rat throve exceedingly, and in the seventeenth century was probably responsible for the Great Plague of London. The black rat, however, was temporarily almost exterminated by the new invasion of this country in the eighteenth century by the brown or Norwegian rat—a stronger and more ferocious animal. The brown rat flourished for about two hundred years, up to the Great War, and its presence was tolerated as long as the economic damage it caused was not too apparent. If it became too obnoxious a desultory hunt with dogs, ferrets, and guns ensued, or some dangerous poisonous agency was tried with more or less success. In 1910 an outbreak of plague in the Ipswich district caused the Local Government Board to issue orders for the suppression of rats, which were held to be the means of spreading the disease. Following this came the Great War, when it became essential to undertake the intensive production and preservation of foodstuffs. This gave a great impetus to the increase of rats and mice in the country, and it was soon found to be necessary to wage war on these injurious rodents. The result was that legislation was introduced and bounties were paid for the destruction of rats.

The Rats and Mice (Destruction) Act, 1919, came into force on January 1st, 1920. Under this Act it is a statutory obligation upon the "occupier" of land or buildings to take such steps as may, from time to time, be necessary and reasonably practicable for the destruction of rats and mice, on or in such land or buildings, and for preventing such land or buildings from becoming so infested. In default the occupier is liable on summary conviction to a fine not exceeding £5, or where he has been served with a notice under the Act requiring him to take such steps, not exceeding £20. The Local Authorities responsible for the administration of the Act are County Councils, County and Metropolitan Borough Councils, Port Sanitary Authorities and the City of London, and, where powers have been delegated, the District Councils.

The administration of the Act as far as the repression of rats in Port Sanitary areas is concerned is vested in the Ministry of Health. In accordance with the International Convention for the Prevention of Plague, to which this country is a signatory, rats on ships have to be destroyed at stated intervals if engaged on foreign trade, and certain ports in this country are empowered to issue certificates either for exemption from this process or giving particulars of the fact when such a process is necessary; such certificates are accepted by the nations who are signatories to the Convention as a proof that every

RATS AND MICE (*Continued*)—
effort has been made to free ships from rats which may be infected with plague.

The Ministry of Agriculture and Fisheries is responsible for the administration of the Act in all areas other than Port Sanitary areas, and in 1919 the Ministry appointed a technical officer who devotes his whole time to advisory work in this connection. The Act is now administered by nearly 700 Local Authorities in England and Wales; north of the Tweed it is administered by the Board of Agriculture for Scotland. Many Local Authorities have set up machinery in an earnest endeavour to suppress rats and mice, and special officers have been appointed to ensure that refuse dumps, sewage works, and property actually vested in Public Authorities are freed from rats. The services of such officers are also available to occupiers of trade and private premises. Where no whole-time Rat Officer has been appointed the Sanitary Inspector generally undertakes this duty in accordance with the Sanitary Officers' Orders of 1922 and 1926.

During the last ten years an earnest attempt has been made by many responsible authorities to control rats and mice. National Rat Week is held during the first week of November in England and Wales, and during March in Scotland. It is not suggested that one week in every year is sufficient to control such relentless foes as these rodents, but it does serve to stimulate repressive measures in an organized manner throughout the country at a favourable period. Every week, however, should be a Rat Week, as one suspects it may become when we realize more fully what an important influence these vermin have on our economic and hygienic well-being.

At the invitation of the French Government the Conférence Internationale du Rat was held at Paris and Havre in 1928, its purpose being to direct attention to the serious menace of rats and mice to mankind. This Conference was attended by seventy-two official delegates representing no fewer than forty-six countries. The exchange of views on the suppression of rats and mice was of great interest, and it was resolved that it was desirable to form an International League and that an Organizing Committee should consider ways and means. In the event of the various Governments adopting the recommendations of the Committee a new Conference was to be organized to study the lines on which the League should be organized.

The control of rats and mice is to a great extent a sanitary one, the proper disposal of household and trade garbage being an important factor. Foodstuffs of every description should receive proper protection from contamination by these loathsome pests, and to this end buildings of all descriptions—especially food stores—should be constructed on rat-proof lines.

The elimination of shelter is of great importance. In towns the indiscriminate erection of temporary sheds for storage purposes is an open invitation to rats to take shelter, and from such centres foraging parties sally forth to commit destruction. The so-called "dead-ends" of sewers furnish ideal homes for rats. If they confined their activities to scavenging the sewers a word might be said in their favour, but

RATS AND MICE (*Continued*)—

unfortunately it is from rats whose shelter is connected with sewers on the one side and human dwelling houses on the other that the greatest menace of all arises. Co-ordinated action by all Local Authorities having sewers under their control is, therefore, an essential step in the repression of rats in larger urban areas.

Farm buildings used for housing animals or storing foodstuffs should be designed to exclude rats. In particular, it is desirable that the construction of buildings should give no opportunity for rats to secure access to the foundations, or to make a congenial dwelling within the buildings themselves.

Owing to its preference for living in close proximity to man and in food warehouses the black rat is much more dangerous as a potential disease carrier than the brown rat. As regards some of our big cities, it is remarkable how the repressive measures against the common brown rat, though successful against this species, have at the same time aided the black rat—especially *R. alexandrinus*—to survive. The result is that in the City of London the Alexandrian rat probably outnumbers the brown rat by four to one.

The actual measures to be adopted for the destruction of rats and mice in any given case are governed by the local conditions. Those whose premises are infested should consult the Local Authority responsible for the administration of the Rats and Mice (Destruction) Act, 1919.

E. C. R.; H. C. L.

RED CLOVER: Varieties and Strains—It is scarcely necessary to emphasize the value of red clover as a forage crop—its productiveness, its high nutritive value, and the important part it plays in maintaining soil fertility—as its wide distribution and its almost universal use are in themselves sufficient testimony to the high esteem in which it is held. Though it is, perhaps, not so productive as lucerne, it has a much wider range of adaptability as regards both soil and climatic conditions than the latter.

The exact origin of cultivated red clover is obscure. It was apparently unknown to the Greeks and Romans, and seems to have made its first appearance as a cultivated crop in Europe in the thirteenth century, but was not introduced into England until the middle of the seventeenth century.

There are grounds for believing that the red clover first introduced into this country from Flanders was an early-flowering, short-lived form; since that time, the crop has undergone considerable modifications and has become differentiated into several more or less distinct forms. Before the advent of the present-day seed distributing houses it was the usual practice for the same seed to be grown in the same districts for generation after generation, and even to-day several cases are known where the same seed has been grown on the same farm for over a hundred years. In course of time, as a result of natural selection, aided no doubt by unconscious selection on the part of the growers, new forms have been produced which are better adapted to the local conditions than the original clover. There is hardly a

RED CLOVER (*Continued*)—
single country in which red clover has been cultivated for some time which does not possess characteristic races that have originated in this way. In this country alone there are five fairly distinctive local strains, namely, English Broad Red, English Late, Vale of Clwyd, Cornish Marl, and Montgomery.

Most of the regional races, or nationalities as they are sometimes termed, though they are often very similar in regard to their botanical characteristics, differ markedly in their agricultural properties, their yielding capacities, length of growing season, rate of growth, leafiness, winter hardiness, permanence, resistance to various diseases, and other characteristics affecting yield and quality of the crop.

All forms of red clover are classified according to their botanical and agronomic characteristics into three main groups, namely, Earlies, Lates, and Wilds. A brief description of the most important characteristics of each of these three groups, as well as of those of the varieties and nationalities generally sown in this country, is given below.

Early Flowering Clovers—The early clovers usually sown in this country are: English Broad Red, Vale of Clwyd, Canadian, New Zealand, American Medium, French, Silesian, Polish, Czechoslovakian. and Chilian. In comparison with the lates they have a laxer and more erect habit of growth; the leaves are on the average larger, and the stems shorter, fewer, and rather more hollow. Most of the earlies have a relatively short resting period; they start active growth about the end of March or early in April—about two to four weeks earlier than the lates. They generally come into flower during the third or fourth week in June, and, unlike the lates, they produce a succession of fresh shoots throughout the growing season.

By virtue of their rapid growth, the earlies usually afford an appreciable amount of stubble grazing, while some nationalities contribute a fair amount of winter keep. They produce far more spring grazing, and earlier hay crops than the lates. In contradistinction to the lates they yield two full crops—hay and aftermath—in the second year. Under the conditions prevailing in this country all the earlies behave mainly as biennials; they usually die back almost completely during the second winter. For this reason, they should be used for one-year leys only, and then only on land particularly suitable for red clover. As all the earlies are highly susceptible to clover sickness they should never be sown on clover-sick land.

English Broad Red—Except that the plants have a slightly more spreading habit and are rather more hairy, English Broad Red is morphologically almost indistinguishable from the other West European early clovers. In all of the trials conducted in this country, English Broad Red has given consistently good results in the second year, being on the average more productive than the foreign earlies. It is undoubtedly one of the best red clovers for stubble, winter, and early spring grazing. It flowers moderately early, about the third week in June, and on suitable land it may be relied upon to give good hay and aftermath crops. Except under very favourable conditions,

RED CLOVER (*Continued*)—

it seldom lasts well into the third year, and is inferior to some of the foreign earlies in this respect.

Vale of Clwyd—This medium late "early" clover is better adapted for the western counties than English Broad Red. At Aberystwyth and in adjacent counties it has proved to be the most productive of the earlies during the second year. It is, however, inferior to many earlies in regard to winter and early spring grazing, but produces very heavy hay crops and quite good aftermath. Though it holds the ground rather better than English Broad Red, like all other earlies, it is only suitable for one-year leys.

American Medium and Canadian—These two clovers, which are very similar in most respects, differ from European clovers in being much more hairy. In comparison with English Broad Red and most of the European earlies they have rather shorter growing seasons. They are less productive in the seeding year, while the amount of winter keep they afford is practically negligible. Despite the fact that they are rather later in starting active growth in the spring, they are generally in flower four or five days earlier than English Broad Red. American Medium from the northern and eastern States and Canadian are among the best of the foreign earlies; they are consistently good croppers, and are hardier and in consequence last better into the third year than the European earlies, but medium reds from the Southern States are not so reliable, nor so hardy.

New Zealand—In general type this clover is intermediate between English Broad Red and American Medium. It has a longer growing season and produces better winter and spring growth than the latter. Although it is somewhat variable as regards its performance, New Zealand clover is more suitable to this country than most of the European clovers.

Earlies from Eastern Europe—The early clovers emanating from Silesia, Poland, and Czechoslovakia are appreciably less hairy than those of Western Europe. Though they are not as a rule as productive as the native earlies, they rank among the best of the European clovers, and are decidedly more hardy than the clovers from southern Europe. Silesian clover is appreciably earlier, and in consequence produces better autumn and spring grazing than most clovers from Czechoslovakia.

Swiss Clovers—These clovers are characterized by their large leaves and their ability to begin growth very early in the spring, Swiss Mat and Mountain Red being the first to start active growth. They may generally be relied upon to give good yields in the second year, but do not, as is sometimes claimed, persist into the third year.

Early Clovers from Western and North-Western Europe—The clovers grown in western France, Brittany, and Holland are not unlike British Broad Red in general appearance. They are all decidedly more hardy and more productive than the clovers from southern Europe, but they cannot be regarded as being as reliable as English Broad Red.

Early Clovers from Southern Europe—Seeds obtained from the south of France and from Italy behave very similarly in this country.

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It has been demonstrated repeatedly that they are totally unsuited to British conditions. They are not sufficiently hardy to withstand even the first winter, with the result that the crops are almost invariably thin in the second year and readily succumb to anthracnose.

Chilean—This is one of the least hardy of the red clovers imported into this country. Under favourable conditions it is capable of yielding excellent crops in the second year, but on account of its lack of hardiness it cannot be recommended except for well-sheltered districts.

Late Flowering Clovers—The late clovers generally sown in this country are English Late, Montgomery, Cornish Marl, Swedish Late, American Mammoth, Russian, Norwegian, Danish, and Altaswede; the last three named are used only to a very limited extent.

In comparison with the earlies, the late clovers form in the spring and early summer dense, leafy tufts. Though they tend to become more erect as they mature, most of the plants retain their characteristic spreading habit of growth, even when in flower. They tiller much more freely than the early clovers, and the stems are longer, more slender, and weaker. As compared with the earlies, they make relatively slow growth in the seeding year. They remain more or less dormant throughout the winter, and are from two to four weeks later than the earlies in starting active growth in the spring, and in coming into flower. On account of the late start they produce only one full crop annually, the aftermath, unless the hay is cut early, being usually comparatively short, but very leafy.

In general, the lates are not very productive in the seeding year, while their contribution to winter keep is almost negligible, but they generally yield much heavier hay crops than the early clovers, and provided the hay is cut early, they produce quite good aftermath. But their outstanding feature from the farmer's point of view is their persistency—they almost invariably produce good crops in the third year, while some varieties last moderately well into the fourth year. Owing to their greater permanence they are more suitable than the short-lived early clovers for inclusion in mixtures which are to be down for more than one year. Under certain conditions, as, for example, on second and third class land, on land infected with clover sickness, and in exposed areas, the lates will usually give better results than the early clovers even in the first year, since they are better able to withstand adverse conditions and are more resistant to *Sclerotinia trifoliorum* and the dreaded Eelworm; none of the lates, however, is completely immune to Clover Sickness, as is sometimes claimed. Another important point in favour of the lates is that they are better able to withstand heavy grazing.

Montgomery and Cornish Marl—These two clovers are so similar that for the present purpose they may be regarded as one and the same variety. They are too slow in maturing to produce much growth in the seeding year. At the approach of winter they form small, dense, leafy rosettes which serve as a protection to the crowns, and which,

RED CLOVER (*Continued*)—
during late spring, develop into widely spreading, very dense, and characteristic leafy tufts. Besides producing practically no winter growth, they are, with the exception of Norwegian Lates, the latest in starting active growth in the spring, and are among the latest in coming into flower, being about four weeks later than English Broad Red and about ten to fourteen weeks later than English Late. Despite their late start, they produce very heavy hay crops, but the aftermath, unless the hay is cut early, is generally disappointing.

The outstanding quality of Montgomery and Cornish marl is the manner in which they hold the ground into the third and fourth year, being superior to all other red clovers in this respect, and on this account they are pre-eminently suitable for inclusion in leys to be down for more than two years. Except on land of low fertility, they are usually slightly less productive than English Lates in the second year under hay conditions, but their superiority in subsequent years is usually very pronounced. Another invaluable characteristic of these two clovers is that they are able to stand adverse soil and climatic conditions and heavy grazing better than most, if not all, other red clovers.

English Late—This is the earliest—being only about ten to fourteen days later than English Broad Red, and one of the most rapid growing of the late clovers. It gives more stubble, winter and spring growth, than any of the other lates, and usually produces in the second year heavier aggregate crops of hay and aftermath than any other clover. Though fairly persistent, it does not last nearly so well into the third year as Montgomery and Cornish Marl; it is also inferior to the latter strain for pasturage.

Though English Late is inferior to Montgomery and Cornish Marl for long duration leys, it should always be used for this purpose in preference to all early and most foreign lates. On many types of soil it will often give better results than the earlies even for one-year leys.

Swedish Lates—These are undoubtedly the best of the foreign lates. As regards their general morphological and physiological characteristics they are intermediate between Montgomery and English Late. In comparison with Montgomery, the plants are less dense and more erect; they have larger leaves and fewer and stouter stems. Swedish Lates resemble Norwegian Lates in that they produce comparatively little growth in the seeding year, and practically none during the winter. The local strains from middle and south Sweden—these are better suited to this country than those from north Sweden—start growth somewhat earlier than Montgomery and develop very rapidly, and generally produce very heavy hay crops, but the aftermath growth is invariably rather poor. Swedish Lates are fairly permanent and can nearly always be relied upon to yield good crops in the third year, but they are seldom able to survive into the fourth year.

Russian and Polish Lates—Except that they are more variable, these clovers are somewhat similar in general type to Swedish Lates. Though they generally give good crops in the second year, they are

RED CLOVER (*Continued*)—
usually less persistent and are consequently not so productive in the third year as Swedish Lates.

American Mammoth—This clover is characterized by its extreme hairiness, stout stems, and large leaves. It produces no winter grazing and is very late in starting active spring growth. Under favourable conditions it is capable of yielding in the second year very heavy, but rather coarse, hay crops, but the aftermath growth is usually very small. It is the least persistent of the lates grown in this country, and consequently it is seldom very productive in the third year.

Wild Clover—Wild Red clover, as met with in the British Isles, may be readily distinguished from the cultivated strains. It flowers very early, usually during April and May. The plants are comparatively small, bearing few short, slender, solid, and wiry stems. The uppermost internodes are long, hence the leafless appearance of the plants. The leaves are small and dark green. The plants are generally either prostrate, ascending or sub-prostrate, rarely semi-erect.

As a fodder crop, Wild Red clover is considerably inferior to most of the cultivated strains, both from the point of view of total yields and palatability. Its growth is practically at a standstill during the winter months. It yields a light hay crop which is ready for cutting even earlier than American Medium, which is the earliest of the cultivated strains. Its aftermath is insignificant. On account of its greater persistency, which enables it to recover fairly rapidly under grazing conditions, it is more suitable for pasture than for hay.

Wild Red, in its present unimproved state, is considerably inferior to the cultivated strains of red clover, both as regards bulk produced and palatability.

Summary—It is evident from this brief survey that the agricultural value of any particular red clover depends to a very large extent on the source of the seed. The numerous investigations with different varieties and strains of red clover that have been conducted in various countries have demonstrated conclusively the superiority of local strains over imported seed. In this country repeated trials have proved that English Broad Red and Vale of Clwyd (earlies), and English Late, Montgomery, and Cornish Marl (lates), are, on the average, better suited to British conditions than the best foreign clover. Of the imported clovers those emanating from the northern temperate regions are far more hardy and therefore much more productive than the clovers from the south of Europe and South America.

(See in relation to this subject Legumes, Breeding of Herbage; Seeds Mixtures; Seeds Mixtures: Controversies Past, Present, and Future.)

R. D. W.

RED CURRANT—See Fruits, Soft.

REFRIGERATION—The application of refrigeration to the manufacture, preservation or transport of agricultural products depends essentially upon the principle that exothermic chemical reactions—which include most of the reactions spontaneously occurring in living systems—are

REFRIGERATION (*Continued*)—

slowed down in rate by lowering the temperature. In typical cases the rate is halved for a drop in temperature of about 10° C. (18° F.). In dealing with complexes of interrelated reactions, such as the respiration of a fruit or the rate of growth of a mould or bacterium, temperature coefficients of the same order are generally found. In such complexes, however, there is the further possibility that the different temperature coefficients of individual reactions may result in a disturbance of the balance, so that the process as a whole may not only proceed at a different rate, but may tend to a different end, when the temperature is changed. Usually the aim of refrigeration is to retard the rate without changing the nature of the process.

The application of cold beyond a certain point leads to ice formation in the material. This often exerts a decisive influence—and a broad distinction may be drawn on this basis between "chilling" and "freezing" methods. Many food materials (especially fruits) are irretrievably damaged by freezing; others (*e.g.*, meat, fish) are less considerably harmed, and may be frozen for long-period storage, although chilling is still preferred for short-period storage.

These two methods correspond roughly—but by no means identically—to the classes of living and non-living stored materials respectively, the disturbance of structure and withdrawal of water in freezing being the more likely to cause irreparable injury in a delicately balanced living system. These classes differ in other essential respects, and it will be convenient to separate them in the following summary. In the living system the main problems are connected with the effect of temperature on the drift of metabolic reactions, which may be slowed down, but must not be arrested; in the non-living system the aim is usually the prevention of change.

Meat—Meat is preserved by refrigeration either in a "chilled" condition at temperatures in the neighbourhood of 30° F., or in a "frozen" condition at temperatures of 10° to 20° F. The distinction, however, is not absolutely clear cut, since "chilled meat" often contains a small amount of ice in its tissues, while in "frozen meat" some 6 to 12 per cent. of the water usually remains unfrozen. Chilling reduces the rate of chemical change (autolysis), and also retards the activities of moulds and bacteria, but it is only possible in this way to preserve meat in good condition for a period of about six weeks—sufficient for the voyage from Argentina to Great Britain, but scarcely for the voyage from Australia, although it has been demonstrated by experimental shipments that selected small consignments of beef can be brought from Australia in fair condition at temperatures of 27° or 28° F., *i.e.*, in a slightly frozen state.

Ordinary frozen meat can be preserved for long periods (twelve months or more) without serious further deterioration, apart from some loss in weight. Unfortunately, with present methods irreversible changes occur during the cycle of freezing and thawing operations, and beef so treated differs considerably from fresh or chilled meat. With mutton the damage is much less marked, possibly because of ana-

REFRIGERATION (*Continued*)—

tomical differences in the muscle fibres, which are smaller and more numerous in mutton than in beef, and New Zealand successfully maintains a huge export of mutton and lamb to Great Britain in a frozen state.

Small pieces of beef can be frozen and thawed reversibly if the rate of freezing is very great (immersion in liquid air or in very cold brine). Large quarters of beef cannot, however, be frozen rapidly, and under the ordinary conditions of slow freezing in air, irreversibility of the changes is shown by the exudation of "drip" from the cut surfaces of the meat on thawing. The "drip" consists of water exuded from the muscle substances, which in its passage through the meat dissolves proteins, salts, and colouring matters, and so contains about 10 per cent. of solid substance; its loss represents, therefore, a considerable decrease in the quality of the meat.

Microscopic examination shows that the slower the rate of freezing the greater the disorganization of the muscle structure, a disorganization which is also shown by the increased rate and extent of autolysis in such material after thawing.

Opinion is not uniform as to the best temperature for the freezing and storing of meat; in Germany (indeed in Europe generally) it may be as high as 20° F., in Australia and New Zealand it is usually from 10° to 15° F., while in America attempts are made to freeze at temperatures as low as $-4°$ F., with subsequent storage at about 15° F. Apart from actual changes during freezing, the temperature of storage must be governed by several considerations: the absence of mould and bacterial growth (which may occur at temperatures as low as 20° F.); the slowing down of deleterious chemical changes, such as those leading to rancidity in the fat; the necessity for preserving rigidity of the carcases, which may otherwise suffer deformation by the weight of superimposed carcases in the store. The amount of ice in the tissues is undoubtedly important, and T. Moran has calculated from dilatometric observations that the percentage of total water frozen out from beef at various temperatures is as follows: at 29° F., 44 per cent.; at 28° F., 60 per cent.; at 26° F., 72 per cent.; at 23° F., 82 per cent.; at 20° F., 88 per cent.; at 10° F., 96 per cent.; at 0° F., 98 per cent.

The rate of thawing is also important, and slow thawing, by providing favourable conditions for the reabsorption of water by the tissues, materially reduces the amount of drip. In Germany meat is sometimes thawed at a steady temperature of 40° F., or sometimes is slowly warmed from 32° to 50° F., the process taking about eighty hours; in this country there seems to be no generally accepted technique.

The initial quality of meat is a factor of great importance in connection with freezing, and it has been definitely shown that the loss of palatability as a result of freezing is much less in the case of the highest quality product. Young muscle can generally be frozen and thawed with less change than muscle from older beasts.

The superficial appearance ("bloom") of meat is often impaired by freezing and cold storage. The surface of a carcase to a depth of 2 to 3 mm. is made up of varying amounts of connective tissue, fat,

REFRIGERATION (*Continued*)—

and muscular tissue. Swelling of the collagen fibres of the superficial connective tissue before freezing may lead to increased opacity of the tissue; chemical changes in the fats and pigmentary changes in the muscles are other factors, and excessive drying will also produce a yellow, withered appearance in exposed muscle. In New Zealand mutton and lamb it has been shown that loss of bloom is due mainly to the drying of exposed or visible muscles and to physical changes produced in the connective tissue by the sweating and refreezing of the carcases.

With chilled meat the main difficulty is the development of moulds and bacteria, which in certain cases may be quite considerable even at 30° F. Scrupulous cleanliness of the meat and care in handling are essential, and the maintenance of a suitable humidity is important, since high humidities (greater than 85 or 90 per cent.) favour mould development, while low humidities may lead, on the other hand, to excessive evaporation. Common moulds on cold-stored meat are *Cladosporium herbarum* (the cause of "black spot"), *Thamnidium chætocladioides*, *T. elegans*, and species of Mucor and Penicillium. The growth of these moulds is superficial, the mycelium penetrating only to a maximal depth of about 4 mm., and they do not confer poisonous properties on the meat, or, unless associated with putrefactive bacteria, render it absolutely unfit for food. Some strains of *C. herbarum* are actually capable of growth at 18° F., and thus may live on frozen meat, but this is exceptional.

The use of fungicidal and bactericidal substances to prolong the storage period of chilled meat has often been suggested—for example, the use of formaldehyde in the Linley process. Such substances may, however, have a deleterious effect on the meat, or the eventual consumer, and their use is prohibited in many cases on these grounds.

The quality of fresh beef is improved by storage for one or two weeks at temperatures of from 32° to 40° F. Improvement is particularly marked in respect of tenderness, due perhaps to changes in the connective tissue brought about by the lactic acid which accumulates in the muscles after killing. There is no change in flavour, but a slight increase in juiciness, which is possibly due to the liberation of water from the gel of muscle protein.

Pork may be frozen with fair success, although lengthy storage is likely to lead to rancidity and to excessive drying. A protective ice glaze is useful in this connection. Bacon may be chilled for short period preservation, or may be frozen hard with satisfactory results at low temperatures (about 5° F.) if the freezing process is rapid. Poultry and rabbits are also regularly preserved by hard freezing.

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REFRIGERATION (*Continued*)—

245-251 T., 1929; Food Investigation Special Report No. 7, "The Preservation of Food by Freezing."

Fish—The possibilities of preserving fish in a chilled condition are very limited owing to the intensity of bacterial activity and other factors; and for any sort of prolonged storage freezing is essential. Freezing in air is sometimes carried out at temperatures of about 10° F., but in modern "quick-freezing" methods much lower temperatures—often below 0° F.—are employed. Freezing by immersion in cold brine offers an alternative method of hastening the process, which is made use of in the methods of Ottesen, Petersen, Piqué, Dahl, Harden-Taylor, Cooke, Kolbe, Birdseye, Zarotschenzeff, Plank, and others.

When cold stored in the frozen state, there may be deterioration due to drying, loss of colour, and loss of flavour. Desiccation is avoided by covering the fish with a glaze of ice by dipping them in cold water after freezing. Wrapping in waxed paper, cellophane, or similar materials is sometimes resorted to, particularly in modern processes of quick-freezing packaged filleted fish.

The slime on the surface and the intestines of fish freshly caught is rich in bacteria, and the mode of handling fish on the fishing vessels and in transit to the markets often encourages the growth of these bacteria, and the invasion of the tissues by other species capable of intense putrefactive activity. Freezing not only checks the multiplication of bacteria, but partially sterilizes the surface of the fish. Moulds do not readily grow on sea fish.

In air-freezing methods a free circulation of the air hastens the extraction of heat, but increases desiccation and loss of colour. The smaller fish are not hung, but are spread on galvanized iron trays, often placed directly on the refrigerating coils. Quick freezing in air necessitates the use of very low temperatures which are costly to maintain, but has the advantage of permitting the formation of a thick and durable ice glaze if this is desired. In the Birdseye process, which may be taken as representative of one type of modern American practice, the fish are filleted, wrapped, and packaged before freezing, and the packages are then frozen between two flexible travelling belts of Monel metal, which make intimate contact one with the top and one with the bottom of the package, and which are cooled by spraying very cold brine on their outer surfaces.

When fish are frozen by immersion in brine there is no loss of weight during the actual freezing process, and subsequent desiccation can be minimized by close packing. So long as the skin of the fish is intact, and provided the process is rapidly carried out, there is little penetration of salt from the brine. Preservation of the tissues is much better than with air freezing, and the texture when thawed out is practically that of fresh fish.

Certain minor defects do, however, develop in storage after such treatment. Herring frozen in brine are at first indistinguishable from fresh fish, but after storage even at a temperature as low as 12° F. they show a browning of the gills (due to chemical reduction of the

REFRIGERATION (*Continued*)—

hæmoglobin), a central opaque white patch in the eyes (due to a change in texture of the lens), and, sometimes, after four to six months' storage, a brownish-yellow discolouration of the skins in patches. None of these changes is due to putrefaction or militates in any way against the food value of the fish.

At a very low temperature (-6° to -10° F.) some frozen fish may be preserved for as long as a year without serious deterioration. At higher temperatures the period is correspondingly shortened. When freezing is rapid the ice crystals formed are mostly small, and consequently the structure of the fish is not seriously disrupted; there is some evidence, however, that if a higher temperature (*e.g.*, 15° F.) is employed for subsequent storage there is a growth of the larger crystals at the expense of the smaller, so that the advantage of quick freezing may be partially neutralized.

The preservation of fish in a "chilled" condition by means of ice is a time-honoured procedure at all stages—on board the fishing vessel, during transport from port to market, and in the retailer's shop. Ice acts as a preservative by slowing the activities of the bacteria, but does not arrest their growth completely, and can only be recommended for employment in comparatively short voyages. It has been demonstrated that by the use of cleanlier and more careful methods on board the trawlers the duration of freshness can be extended from six to seven days to ten to twelve days, and a much larger proportion of the total catch can be landed fresh. But the present-day necessity for seeking fishing grounds farther afield, as Iceland, Greenland, and the Barentz Sea, seems likely to lead to a situation which can only be met by the installation of brine-freezing equipment on long-distance fishing vessels.

LITERATURE.—Food Investigation Special Reports (*H.M. Stationery Office*): No. 4, "Methods of Freezing Fish"; No. 37, "Handling and Stowage of White Fish at Sea"; J. Piqué, "The Transport of Fresh Fish," *J. Inst. of Transport*, viii., April, 1927; Quick-Freezing Symposium in *Food Industries*, vol. ii., April, 1930; H. F. Taylor, "The Refrigeration of Fish," *U.S. Dept. Comm. Bur. Fish. Doc.*, No. 1016, 1927.

Eggs—Eggs are very definitely a seasonal product, and the employment of cold storage is becoming an important factor in steadying the supply. They may be preserved—under ideal conditions for at least twelve months—by storage at a temperature just above their freezing point. The "frozen" eggs of commerce are a quite different product, consisting of egg yolk and white either separate or mixed, but in either case removed from the shell, and frozen in tins at temperatures as low as 10° F., sometimes with the addition of common salt or sugar. The uses of this product are practically limited to large-scale culinary employment.

Chilled eggs, on the other hand, may be practically indistinguishable from fresh eggs even after prolonged storage, if the conditions are appropriate. Egg white freezes at about 31·2° F., and yolk at 30·8° F.; whole eggs may easily be supercooled, but this state is of

REFRIGERATION (*Continued*)—

course unstable. Actual freezing generally results in a cracking of the shell through expansion of the contents, but this may be avoided if a contraction by evaporation has previously occurred or been artificially brought about, and so far as the contents are concerned, freezing is reversible if carried out at a temperature not lower than 21° F. There is thus a theoretical possibility for the storage of frozen eggs in shell, but at present the invariable practice is to maintain a temperature of 32° to 34° F. in the storage chamber.

Humidity is important since it largely governs, on the one hand, the rate of development of moulds on the eggs, and on the other the rate of loss of water. Evaporation leads to a shrinkage of the egg contents and the enlargement of the air chamber under the shell. It can be greatly reduced by coating the shell with an oil or wax, thereby more or less closing the pores; paraffin wax softened by admixture with medicinal liquid paraffin makes a suitable coating material, and machines are available to brush the surface of the egg with such a substance, but the process involves considerable labour and has not been adopted on any considerable scale.

Moulds and bacteria are a very serious source of danger; they exist on the outside of the shell from the first, and although the shell and shell membranes offer a certain resistance to invasion, this is not effective if conditions are otherwise favourable to their growth. Among fungi species of *Cladosporium, Penicillium, Sporotrichium, Mucor* and *Thamnidium* are particularly common. Their development can be checked by maintaining a relative humidity not exceeding about 80 per cent. in the atmosphere around the eggs. Surface sterilization with mercuric chloride (1 : 1,000) is very effective, but not of course commercially practicable; sealing with wax also delays mould growth. An alternative method due to Lescardé, and very generally employed in France, is to store the eggs (at about 34° F.) in an atmosphere of carbon dioxide (85-90 per cent.) and nitrogen (15-10 per cent.), after preliminary treatment in a vacuum to remove atmospheric oxygen; the moulds are then unable to develop. Gas-tight containers must of course be employed for storage under these conditions.

The chief changes in an egg during storage are the loss of its characteristic "bloom," the increase in size of the air chamber, the weakening of the vitellin membrane (round the yolk), and an increased fluidity of the thick inner portion of the white, which in a fresh egg clings closely round the yolk. After long storage the white may become yellowish in colour. There is a transfer of water from white to yolk—rapid when the egg is first laid, but very slow after some time in cold storage. Chemical changes proceed only very slowly in the stored egg. The acidity gradually decreases, perhaps solely through the loss of carbon dioxide which escapes from solution in the tissues.

Practical considerations in the cold storage of eggs are that only fresh eggs should be employed, preferably not more than a week old, and above all only eggs with clean shells. Eggs should be candled before and after storage. The air in the store should be circulated periodically if not continuously, and should be renewed as soon as the

REFRIGERATION (*Continued*)—
slightest odour becomes apparent. The storage chamber and all packing materials should be scrupulously clean and free from odour, since eggs are extremely susceptible to "taint." Ozone in a concentration of 1 part per million has been found to have good results in removing odours from egg stores, and possibly also has some utility in preventing mould growth. On removal from the store the eggs must not be allowed to sweat, but should be gradually raised in temperature if possible in a separate "defrosting" room.

Literature.—Food Investigation Special Report (*H.M. Stationery Office*), No 26, "The Storage of Eggs"; F. Lescardé, "L'œuf de poule: sa conservation par le froid," Dunod and Pinat, Paris, 1908; A. Monvoisin, "La conservation par le froid des denrées perissables," Dunod, Paris, 1923; J. Piqué, "Changes in the Quality of Eggs during Storage and Transport," *J. Roy. Sanitary Inst.*, vol. xlvii. S., 1926; M. K. Jenkins, "Commercial Preservation of Eggs by Cold Storage," *U.S. Dep. Agric. Bur. Chem. Bull.* 775; M. E. Pennington and G. A. Horne, "Effect of Conditions in Cold Storage Rooms on the Keeping Quality of Eggs," *Proc. 4th. Internat. Congr. of Refrig.*, vol. i., 200-221, 1924.

Butter—Butter can be preserved over a wide range of temperature, from slight chilling at about 40° F. down to hard "freezing" at zero F. At temperatures between 35° and 40° F. it remains in reasonably good condition for two months or even longer, but the modern tendency is to use much lower temperatures, with a progressive increase in the length of storage life and in the retention of flavour.

During storage there are changes in acidity, an increase in soluble nitrogen, and a decrease in the number of micro-organisms. There is usually some loss of aroma, of texture, and (in the superficial layers) of colour. There is also a loss of water by evaporation, which is diminished the lower the temperature and the higher the relative humidity. Shrinkage by evaporation can be lessened by more thoroughly incorporating the moisture in the fat during working.

The keeping properties of butter depend largely on its composition and the methods of manufacture. Butter from sweet cream has better storage qualities than that from ripened cream, and a partial reduction of the lactic acid in cream by means of sodium bicarbonate or lime improves the keeping quality. The amount of air inside the butter—which varies from 1 to 4 or 5 c.c. per 100 grams—is also of some importance as helping to determine oxidations and the development of aerobic micro-organisms.

The development of "off flavours" in cold storage is a frequent source of loss. A storage flavour is frequently due to tainting by some odorous material inside the store, and scrupulous cleanliness of the chamber and packing materials is essential; only well-seasoned timber should be used for the boxes in which the butter is to be stored. An oily flavour is not uncommon. Tallowy butter has the flavour of tallow; rancid butter that of butyric acid. A fishy flavour is one of the commonest defects, and is caused by the decomposition of lecithin

REFRIGERATION (*Continued*)—

with the production of traces of trimethylamine. A metallic flavour is also of fairly frequent occurrence.

Under normal conditions there is no multiplication of bacteria: the aqueous phase is a 14 to 15 per cent. salt solution which is above the growth limits of ordinary bacteria. Enzymes apparently still function to a certain extent even at 0° F., and may occasionally be a factor in deterioration. Oxidations by atmospheric oxygen, in which the ethylenic linkages of the unsaturated fatty acids are attacked, are a probable cause of the tallowy flavour; it is known that the oxygen of the air incorporated in butter disappears during storage. In other cases deterioration is due to the growth of moulds, but this should be prevented by strict attention to the thorough sterilization of equipment and to general cleanliness, by pasteurizing the cream, by treating the parchment papers with hot brine solution, by waxing the boxes, and by the use of clean water for washing.

The Cooling of Cream—For the production of butter of a good texture it is important that the cream should be thoroughly cooled after pasteurization (at about 190° F.). This is effected in two stages: a water cooler followed by a brine cooler, which latter should be of sufficient size to cool the cream to 35° to 40° F. with brine at 32° F. From the brine cooler the cream may be run into vats fitted with submerged brine coils, and should be kept at a low temperature until churned.

LITERATURE.—L. A. Rogers, "Fundamentals of Dairy Science," Chem. Cat. Co., New York, 1920; "Influence of Acidity on Flavor and Keeping Quality of Butter," *Iowa Agric. Expt. Stat. Bull.* 207, 1922.

Cheese—The preservation of cheese by cold storage is intimately associated with the ripening process which is generally necessary to convert the green or uncured cheese, which has little flavour, and a tough rubber-like consistency, into an edible product with a satisfactory taste and body. The changes are due partly to the action of lactic and other acids which react with insoluble calcium salts of the milk, forming calcium lactate, calcium paracaseinate, etc.; partly to the rennet enzyme which digests the calcium paracaseinate forming peptones and caseoses; partly to the action of micro-organisms such as the lacto-bacilli, which change casein and paracasein into soluble protein derivatives. Temperature affects the rate of these reactions, as well as the rates of subsidiary processes such as the loss of water and the development of moulds, and there is apparently an optimal rate of ripening, and consequently an optimal temperature, which results in the most satisfactory product. This temperature is generally so low as to involve refrigeration. In general, cheeses ripened slowly in the cold have a characteristically milder flavour than those ripened at higher temperatures.

For the ripening of Cheddar cheese the most favourable temperature is generally stated to be between 35° and 40° F., but it must vary with the composition of the cheese and the marketing conditions. At this temperature ripening is slow, a possible disadvantage from

REFRIGERATION (*Continued*)—

some points of view, an advantage when transport over long distances, *e.g.*, from New Zealand to Great Britain, is being considered, but it proceeds very regularly, the texture is generally closer and freer from holes, and the growth of gas and taint producing organisms is more completely arrested.

LITERATURE.—L. van Slyke and W. V. Price, "Cheese," New York, 1927; L. A. Rogers, "Fundamentals of Dairy Science," Chem. Cat. Co., New York, 1928; W. Wright, "Application of Refrigeration and its Effect upon the Ripening and Cold Storage of Cheddar Cheese," *Proc. 4th. Internat. Congr. of Refrig.*, i., 956-966, 1924.

Milk—Chilling and freezing are both employed in the preservation and transport of milk. Chilling reduces the rate of bacterial growth, and the intensive application of refrigeration from the time of milking greatly prolongs the keeping period. The transport of cooled milk in insulated tanks is one aspect of this procedure. The normal freezing point of milk is 31·0° F.; the storage temperature is usually not lower than about 34° F.

Actual freezing destroys the physical structure and causes a separation of free fat, but in many cases the changes can be restored by subsequent pasteurization and homogenization. In the frozen state milk can be preserved more or less indefinitely.

The use of refrigeration in the preparation and preservation of ice cream can only be briefly mentioned. The freezing of ice cream is apparently a reversible process. The time and temperature of freezing are important factors in determining the texture of the product. After freezing the ice cream is hardened for about twelve hours at a still lower temperature (5° to 15° F.).

LITERATURE.—L. A. Rogers, "Fundamentals of Dairy Science," Chem. Cat. Co., New York, 1928; J. T. Bowen, "Application of Refrigeration to Dairying in the United States of America," *Proc. 5th Internat. Congr. of Refrig.*, 1928.

Fruit—The basal fact upon which the use of refrigeration for the preservation of fresh fruit, vegetables, and other living tissues depends is that most chemical reactions and physical processes are increased in rate with a rise of temperature, and conversely, are slowed down with a fall of temperature. At low temperatures there is a retardation of the predetermined sequence of events of senescence, as in the case of fruits, or of growth, as in the case of entire plants, bulbs, etc. The aim of successful storage is to control the rate of the changes which must take place during storage, to retard or accelerate them at will, whilst inducing the least possible alteration in their normal character. And it is now generally recognized that there is an optimum temperature of storage, not merely for each kind of fruit, but also, within the kind, for each variety.

1. *Apples*—Owing to its importance as a food product, a very intensive study has been made of the effects of temperature upon the storage life of the apple. It will be convenient to consider in detail

REFRIGERATION (*Continued*)—
the factors which influence the storage life of the apple at low temperatures, since, in a general way, they apply in the case of other fruits.

A definite quantitative relationship between length of storage life and temperature of storage has been established for a number of English varieties of apples. This relationship is shown diagrammatically by Curve A in Fig. 26, from which it can be seen that a variation in temperature of 1° F. may alter the length of the storage life by approximately 10 per cent., while there is nearly a 100 per cent. difference in effect between a storage temperature of 32° F. and one of 42° F. At higher temperatures wastage during storage is almost entirely due to fungal rotting. As a rule fungi can enter and rot the fruit when a certain degree of senescence has been reached, so that the relation between temperature and the length of storage life is essentially that between temperature and the rate of the changes due to senescence. At lower temperatures—well above the freezing point of the tissues—functional disease may be the main cause of wastage, due to disturbances of what has been called the metabolic balance of the tissues (F. Kidd and C. West, "Temperature and Metabolic Balance in Living Plant Tissues," *Proc. 4th Internat. Congress Refrig.*, London, p. 170, 1924). A given change in temperature will affect the rates of different chemical reactions and physical changes to a different degree. For a given change in temperature there must necessarily follow a change in the relative proportions of the various substances which make up the chemical constitution of the tissues, and therefore on purely theoretical grounds it follows that in a complex of interdependent reactions, such as is presented by the living plant or plant organ, the effect of a change in temperature must be a dual one: first, upon the net speed of the various reactions; and, secondly, upon the metabolic balance and chemical composition of the tissues. It has been established that, for every variety of apple tested, there exists a critical lower limit of temperature below which the fruit cannot be stored for any considerable period without depreciating in flavour and condition, eventually breaking down and becoming unfit for human consumption. The extreme case of this abnormal condition, in which the flesh shows a brown discoloration, has been termed low temperature internal breakdown (F. Kidd and C. West, *Ann. Rept. of the Food Investigation Board, London*, p. 42, 1927; H. H. Plagge, *Iowa Agric. Expt. Stat. Res. Bull.* 115, 1928).

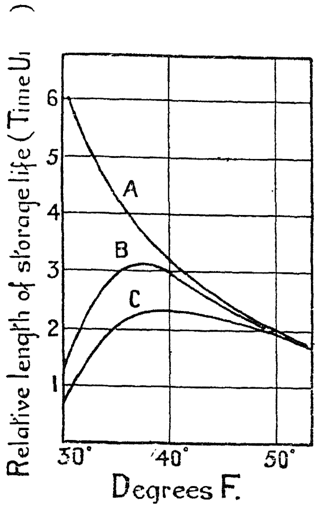

FIG. 26.

Curves B and C of Fig. 26 depict the relation between the length of storage life and the temperature of storage of two varieties of apples,

REFRIGERATION (*Continued*)—

which are characterized by different degrees of susceptibility to low temperature internal breakdown. These varieties are the King Pippin (very susceptible—Curve C in the diagram) and the Bramley's Seedling (moderately susceptible—Curve B). The relation for a very resistant variety, Newton Wonder, is represented by Curve A in the diagram.

It must be recognized that the fruit when it leaves the tree has already a predetermined term of life which, while it may be curtailed or extended by variations in the storage conditions, is definite for any given set of conditions. Experimental storage trials have shown that the storage life of the apple at any given storage temperature may be markedly influenced by nutritional factors, such as climate and soil, and by a number of other controllable pre-storage or orchard conditions. The following examples illustrate the effect upon the life of Bramley's Seedling apples in cold storage of three of these factors—namely, the soil, climate, and the age of the tree respectively.

In a small area near Wisbech having uniform climatic conditions, four plantations showing a wide range in soil texture were selected. Comparable storage trials were conducted with the apples from each of these plantations with the following result:

BRAMLEY'S SEEDLING APPLES FROM THE WISBECH AREA (1925-26).

Plantation.	*Type of Silt.*	*Commercial Storage Life at 34° F. (Weeks).*	*Mean Storage Life at 34° F. (Weeks).*
A	Heavy	34	41
B	Medium heavy	21	25
C	Light	20	23
D	Very light	16	19

It will be seen that at 34° F. the apples off the heavy soil kept twice as long as those off the lightest soil.

In order to ascertain the effect of the climatic conditions on the storage life of apples, cold storage trials were carried out during eight seasons with apples from the same plantation. Apart from marked differences in the date of picking, which presumably depends on the climatic conditions, the latter constitute the only factor which is known to have changed from year to year. Data for the average temperature of the air, the total rainfall, and the hours of bright sunshine were recorded for this area. It must be borne in mind that these measurements of the conditions are incomplete, although most of the unmeasured factors are determined, as regards their nature and amount, by the factors of temperature, rainfall, and sunlight. Hence, the comparisons between seasons are necessarily qualitative in character. The results are shown in the following table, and indicate that good keeping quality is associated with warm, dry weather during the few weeks preceding the date of gathering.

REFRIGERATION (*Continued*)—

STORAGE LIFE AND CLIMATIC CONDITIONS PRECEDING GATHERING.

Season.	*Date of Gathering.*	*Mean Storage Life at 34° F.** (*i.e., to 50 per Cent. Wastage*).	*Weather Conditions during the Four Weeks preceding Gathering.*		
			Average Air Temperature.	*Total Rainfall.*	*Bright Sunshine.*
		Days.	°F.	Ins.	Hours per day.
1920-21	24.9.20	280	55·8	1·5	3·7
1921-22	27.9.21	310	58·6	0·7	6·0
1922-23	9.11.22	150	48·8	1·1	4·4
1923-24	3.10.23	200	54·9	2·4	5·6
1924-25	23.10.24	140	51·2	3·9	3·5
1925-26	6.10.25	150	53·2	2·6	3·7
1926-27	Crop	too small	for experi	mental	work
1927-28	27.10.27	150	51·2	2·0	3·6
1928-29		No experi	ment		
1929-30	13.10.29	220	56·0	0·9	5·2

With regard to the age-of-tree factor, it would appear that under cold storage conditions the apples off young trees (*i.e.*, under ten years old) are poor keepers.

EFFECT OF AGE OF TREE UPON THE KEEPING QUALITY OF BRAMLEY'S SEEDLING APPLES.

Age of Tree.	*Mean Storage Life at* 34° *F.*
6 years.	20 weeks.
11 years.	27·5 weeks.

The most obvious storage factors, other than temperature, which influence the life of apples are the composition and the humidity of the storage atmosphere. It has been shown, at first experimentally, but later by commercial practice, that by control of the change in composition of the storage atmosphere brought about by the respiration of the fruit—namely, a reduction in the percentage of oxygen and a corresponding increase in the percentage of carbon dioxide—a definitely retarding effect upon the rate of respiration and the ripening of the stored fruit can be obtained (" Gas Storage of Fruit," Special Report No. 30 of the Food Investigation Board, London, 1927). The important rôle which temperature plays in the operation of this "gas" storage method has recently been emphasized. It appears that optimum results can be obtained at temperatures just above the limit at which susceptibility to low temperature breakdown commences (F. Kidd and C. West, *J. Pomology and Hort. Sci.*, viii., p. 67, 1930).

* The wastage at this temperature was due almost entirely to low-temperature breakdown.

REFRIGERATION (*Continued*)—

A detailed summary of the main chemical, physiological, and physical changes which accompany senescence in the apple fruit at low temperatures is given in the *Annual Reports of the Food Investigation Board* for the years 1920-30 inclusive. In these reports references are given to recently published papers dealing with this subject. In brief it can be said that so far no simple relation has been found between keeping quality and the concentration of any of the constituents of the apple which have been estimated. The generalization which has been found to hold most widely is that good keeping quality goes with a low content of nitrogen and with low respiratory activity.

Unfortunately, good keeping quality is often not associated with other characters which constitute good quality—for example, apples with a high content of nitrogen, although usually of excellent flavour, are notoriously bad keepers, both at ordinary and at low temperatures.

The recent investigations of Zilva and his collaborators have shown that no loss occurs in the vitamin C content of Bramley's Seedling apples stored in air at 37° F. for five months.

2. *Pears*—The evidence obtained from published work on cold storage of pears shows conclusively that each variety should be considered separately. For many varieties, including such commercially important ones as William's Bon Chrêtien, Doyenne de Comice, Conference, Winter Nelis, etc., a lower storage temperature than that for apples has been advocated, 30° to 34° F. having generally given satisfactory results. If good market quality is to be obtained, it is necessary to allow the fruit to ripen at a higher temperature (60° to 65° F.). Owing to a difference in the nature of its skin the pear is more susceptible to water loss than the apple, and the importance of the humidity of the storage atmosphere has frequently been emphasized.

The potential life of the pear in cold storage depends largely upon a number of orchard and other pre-storage factors, one of the most important of which is the stage of maturity at the time of gathering. When picked too immature the pears wilt badly and ultimately develop only inferior quality. On the other hand, pears picked after the optimum stage of maturity lack, when ripe, their characteristic juiciness and rapidly develop a functional disease which is known as core-breakdown. In the United States of America a considerable amount of attention has recently been given to the question of determining the optimum stage of maturity for gathering pears, and a pressure test and a colour chart have now been standardized for the Bartlett variety.

For details of the chemical, physiological, and physical changes occurring in the pear fruit, in particular the Bartlett and Conference varieties, during its senescence at low temperatures reference should be made to the list of papers given: *Ann. Repts. of the Food Investigation Board, London,* 1925-26; J. R. Magness, *J. Agric. Res.*, xix., p. 473, 1920; E. L. Overholser and L. P. Latimer, *Bull.* 377, *Agric. Expt. Sta., Berkeley, California,* 1924; H. Hartman, *Oregon Agric. Expt. Sta. Bull.* 216, 1925; V. A. Putterill, *Science Bull.*, No. 70, *Dept. Agric.*

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Union of S. Africa, 1928; J. R. Magness, H. C. Diehl, and F. W. Allen, *U.S. Dept. Agric., Techn. Bull.* 140, 1929.

3. *Plums*—The stone fruits, like the pomaceous fruits, show marked varietal differences in their response to storage at low temperatures, the storage life of different varieties at a temperature of 32° to 34° F. ranging from two weeks (*e.g.*, Pond's Seedling) to nearly sixteen weeks (*e.g.*, Wickson).

The storage life of plums is greatly influenced by the degree of maturity and by the weather conditions when gathered.

Plums afford another interesting example among the relatively hardy fruits of injurious effects resulting from a displaced metabolic balance at low temperatures. The behaviour of plums in this respect is in many ways comparable to the behaviour of the apple as described above. The ripening which proceeds at ordinary temperatures, and which is generally described as normal, results in a sweet, juicy, and coloured fruit of good flavour. At low temperatures the plums often do not attain to this condition, but whilst retaining a perfect external appearance, become gelatinous in consistency, lack their normal flavour, and eventually develop internal browning, especially round the stone (F. Kidd and C. West, *Ann. Rpt., Food Investigation Board, London*, 1923; E. L. Overholser, *Berkeley, California Agric. Expt. Sta. Bull.* 344, 1922).

4. *Peaches and Apricots*—The published data on the cold storage of peaches are very meagre. It would appear from the investigations of W. D. Bigelow and H. C. Gore (*U.S. Dept. Agric., Bur. of Chem., Bull.* 97, 1905) that the maximum storage life of peaches at 32° F. varies from twenty-eight to sixty-three days. They remark that at the end of three to four weeks the flesh of the peach may begin to discolour and the flavour may become greatly impaired. The chemical changes that occur during storage at 32° F. were determined and compared with those occurring at 54° to 59° F., and at 77° to 86° F. It was found that the chemical changes at 32° F. differed considerably from those taking place at the higher temperatures.

For a late variety of apricot, R. Plank (*Beih. zur Zeitschr. für die gesamte Kälte-Industrie*, Ser. 3, Heft 3, 1928) records a storage life at 32° F. of from three to four weeks.

5. *Cherries*—For a number of varieties of cherries, Plank (*Beih. zur Zeitschr. für die gesamte Kälte-Industrie*, Ser. 3, Heft 2, 1927; Ser. 3, Heft 3, 1928) recommends a storage temperature of 32° to 34° F., and a relative humidity of the storage atmosphere of 80 to 90 per cent. He claims that under such conditions cherries can be kept in good condition for periods varying from two to seven weeks.

6. *Citrus Fruits*—From a consideration of the published work on the cold storage of citrus fruits it is difficult to arrive at any generalized conclusion regarding the optimum temperatures for storing oranges, lemons, grape fruit, and naartjes. A temperature of 40° F., or over, is usually advocated for citrus fruit, and in the case of naartjes 43° to 48° F. has been recommended. In spite of the greater retardation of ripening and the reduction in wastage due to fungi and other organisms

REFRIGERATION (*Continued*)—

at temperatures below 40° F. serious losses from a functional disease known as "skin pitting" may occur. Skin pitting is another example of the so-called low temperature diseases of fruit, and appears as a number of brownish areas on the skin of the fruit, completely ruining its market value. Moreover, a bitter taste may develop in some of the affected fruits. It has been stated that this type of skin injury may be largely controlled by special "curing" treatments of the fruit prior to storage, but this point requires further investigation. There is also evidence that oranges may be injured by storage at 34° F., the injury only becoming apparent, in increased fungal rotting, after the fruit has been removed to higher temperatures.

A comparative study of the chemical changes taking place in grape fruit stored at 32° and 70° F. showed that whereas at the higher temperature there was evidence of an increase in acidity or a decrease in total sugars or both—that is, the ratio of total sugar to acid decreases—at the lower temperature the reverse is true. There is an increase, or at least not a decrease, in acidity at 70° F. as compared with a decided decrease at the lower temperature, thereby indicating that some of the processes which go on in the fruit at ordinary temperatures are modified when the fruit is placed in cold storage (L. A. Hawkins, *J. Agric. Res.*, xxxii., No. 5, p. 263, 1921; M. R. H. Thomson, V. A. Putterill, and G. Hobson, "Investigations on Export Citrus Fruit from South Africa during 1921"; M. N. Kidd and R. G. Tomkins, *Ann. Rpt. Food Invest. Board, London,* 1927; *J. Council Sci. and Indus. Res. Australia*, iii., No. 2, 1930).

7. *Pineapples*—South African pineapples have hitherto been carried to England at a temperature of 34° to 36° F., or 38° to 42° F., depending on the nature of the other fruit in the hold, but R. Davies ("Storage Investigations of Pineapples in South Africa," *Union S. Africa Dept. Agric. Sci. Bull.* 71, 1928), using South African pineapples of the Queen variety, has recently shown that the use of a higher temperature than 42° F. should lead to a considerable improvement in the condition of the fruit when it reaches the English market. Probably a temperature of 45° F. would also be the most suitable for the other varieties imported, though actual evidence is as yet lacking.

8. *Tomatoes*—The effect of storage at low temperatures upon a large number of varieties of tomatoes has been investigated in England, Germany, and the United States. The results obtained agree in showing that tomatoes are injuriously affected by storage for more than a few days at temperatures below about 50° F. The harmful effect is indicated by failure to ripen and develop normal colour, and by abnormally rapid decay on removal to ordinary temperatures. Results obtained from storage trials at various temperatures carried out by J. Barker (*Ann. Rpt. Food Investigation Board, London,* p. 43, 1927), both with green and fully coloured tomatoes, are presented graphically in Fig. 27, which shows the rate of wastage in comparable samples of fruit kept at 34°, 50°, and 60° F. respectively

The greater rate of wastage at 50° F. than at 60° F., and the very rapid wastage in the sample transferred from 34° to 60° F. after

REFRIGERATION (*Continued*)—

fourteen days at 34° F., indicate the injurious effect of storage at 50° F. and at 34° F. respectively.

It should be noted that the injurious effect of storage at 34° F. is not reflected in the rate of wastage while the fruit is kept at that temperature, but becomes apparent after removal to higher temperatures. Storage at 34° F. may thus be of value if consumption occurs before the fungal rotting which follows removal from storage has begun, viz., within twenty-four hours. Storage at 34° F. might, therefore, be recommended for the preservation of tomatoes as provisions on ships.

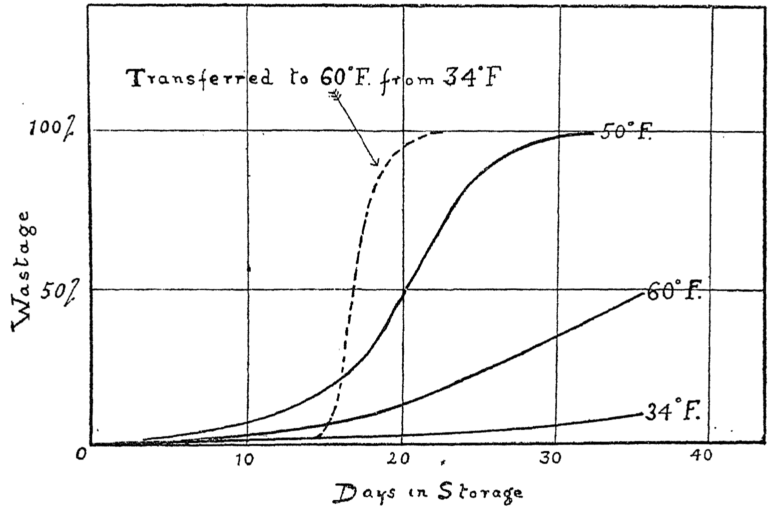

FIG. 27.

It is thus evident that the extension of the period of ripening and senescence of the tomato to any considerable degree by cold storage is not feasible. The marketing period may be extended some three or four days by storage at 34° F. without injury to the tomato, and such short-period storage might be of value in commercial practice during hot week-ends or temporary gluts. The experiments suggest that the maximum extension of the marketing period would be obtained by storage at a temperature between 50° F. and 60° F., but this suggestion needs confirmation (H. C. Diehl, *U.S. Dept. Agric.*, *Circular* 315, July, 1924; J. Barker, *Ann. Rpt. Food Investigation Board, London,* p. 43, 1927; R. Plank, *Beih. zur Zeitschr. für die gesamte Kälte-Industrie,* Ser. 3, Heft 2, 1927; Ser. 3, No. 3, 1928).

9. *Grapes*—According to Plank (*Beih. zur Zeitschr. für die gesamte Kälte-Industrie,* Ser. 3, No. 2, 1927) grapes can be stored satisfactorily at 32° to 34° F. for a period of four weeks, provided that a high relative humidity of the storage atmosphere is maintained.

10. *Avocados*—Data published by E. L. Overholser ("Some Effects of Temperature upon the Ripening and Keeping of Fruits," *Proc. In-*

REFRIGERATION (*Continued*)—

ternat. Congress Plant Sci., ii., p. 999, 1929) indicate that for most varieties of avocados a storage temperature of 4·5° C. gives the best results, the fruit ripening satisfactorily in storage, or subsequent to removal, and attaining excellent quality. Furthermore, at this temperature the ripening was retarded sufficiently to prolong appreciably the marketing period. At lower temperatures the skin tended to exhibit a scalded appearance, the flesh remained firm but turned brown, and the fruit after removal from storage subsequently failed to ripen and soften properly. The following table, taken from Overholser's paper, shows the average keeping quality of certain varieties of avocados stored at their optimum temperature:

Variety.	*Average Date Stored.*	*Year of Tests.*	*Optimum Storage Temperature.*	*Period of Maximum Storage (Days).*
Dickinson ..	July 4	1921	4·5° C.	68
Royal ..	March 7	1920	0·0° C.	60
Taft ..	July 4	1924	4·5° C.	56
Queen ..	July 8	1921	4·5° C.	54
Spinks ..	May 19	1920, '21, '24	4·5° C.	47
Sharpless ..	November 22	1921	4·5° C.	41
Challenge ..	March 7	1920	2·0° C.	40
Rey ..	June 9	1920	2·0° C.	31
Fuerte ..	March 11	1920, '21	7·0° C.	30
Kist ..	June 9	1920	2·0° C.	26

11. *Berries and Small Fruits*—The storage of berries and other small fruits presents a problem which differs considerably from the storage of the more hardy and longer keeping fruits. In the case of the former, the most that can be hoped for from cold storage is the preservation for a comparatively short period of the attractive appearance and fine flavour of the fruit, and the great bulk of the small fruit held in cold storage is placed there either to tide over very brief intervals, such as week-ends, until it can be marketed or placed in the hands of the consumer. In commercial practice, small fruits are sometimes cold stored for a few days or weeks for speculative purposes, the fruit, which is extremely perishable, being bought when market prices are low and kept in cool storage until prices have advanced.

Jam manufacturers and canning establishments also make use of mechanical refrigeration for the storage of small fruits during glut periods; but in certain cases where the fruit can be utilized immediately after removal from storage—as, for example, in jam making—freezing temperatures, usually from 5° to 12° F., can be usefully employed. In the completely frozen condition such fruits may be kept for long periods in a condition suitable for the manufacture of jams and preserves. Other fruits, *e.g.*, peaches, have been stored for long periods in the frozen condition for use in the manufacture of ice cream, etc.

In this connection it is useful to recall the observations of Onslow

REFRIGERATION (*Continued*)—

(*Ann. Rpt. Food Investigation Board, London,* p. 19, 1920), who found that, on the basis of the presence or absence of the catechol-oxygenase system, fruits could be grouped into two classes. The first includes the apple, quince, pear, plum, cherry, peach, apricot, medlar, strawberry, banana, grape, fig, and mulberry. The above fruits contain two enzymes, a peroxidase and an oxygenase, and a substance with the catechol grouping—that is, the complete system constituting an oxidase. The oxygenase catalyzes the oxidation of the catechol substance with the formation of a peroxide, and the peroxidase decomposes the peroxide with evolution of active oxygen. Such a system is capable of transferring oxygen from the air to many oxidizable substances in the fruit. After death of the tissues this oxidase system becomes uncontrolled and brings about rapid destructive oxidation, accompanied by discoloration of substances in the tissues. Hence, after freezing, which kills the fruit, the tissues may be considerably changed by this oxidation process.

The second class includes the orange, lime, lemon, grape fruit, raspberry, blackberry, red currant, black currant, gooseberry, pomegranate, pineapple, melon, and tomato. These fruits contain only a peroxidase. No oxygenase or catechol substances could be detected. Hence, there is no system for transference of oxygen after death, and no discolouration of the tissues takes place.

The length of time small fruits can be kept in cold storage depends largely upon the variety, the conditions under which they are grown, and the methods of handling. Small fruits intended for cold storage should be gathered when well matured and almost fully coloured, and only sound, firm fruits should be selected. When gathered during damp weather soft fruits are extremely susceptible to fungal rotting; under such conditions rapid cooling is essential. For storage over short periods a temperature of 36° to 40° F. will generally give satisfactory results, but for storage over longer periods a temperature of 30° to 34° F. is recommended. Strawberries have been kept in good condition in cold storage from one to two weeks; raspberries, not more than two weeks; blackberries and dewberries, a week to ten days; currants and gooseberries, two to four weeks; whilst cranberries have been cold stored throughout the winter.

After removal from cold storage berries and other small fruits usually begin to break down within a few hours, the time depending largely upon the prevailing humidity and temperature. Various methods of reducing or preventing condensation on the surface of the fruits after removal from cold storage have been investigated and recommended, but even under optimum conditions the fruits usually begin to break down within a few hours, the time depending largely upon the prevailing atmospheric conditions—*e.g.*, temperature and humidity (F. Kidd and C. West, *Annual Reports of the Food Invest. Board, London*; S. H. Fulton, *U.S. Dept. Agric. Bur. Plant Indus., Bull.* 108, 1907; R. Plank, *Beih. zur Zeitsch. für die gesamte Kälte-Industrie,* Ser. 3, Heft 2, 1927, p. 5; Ser. 3, No. 3, 1928).

12. *Mangoes*—J. E. Higgins and E. S. Punzalan (*Philippine Agric.,*

REFRIGERATION (*Continued*)—

xiii., No. 10, p. 443, 1925) compared the effects of temperatures of 36°, 40°, and 50° F. upon the keeping properties of two varieties of mangoes, and found that sound, green, but fully matured mangoes could be stored in satisfactory condition for at least eighteen days at the lowest temperature tested.

After thirty-five days at 36° or 40° F., areas of a dull steel-grey colour appeared on all the fruits, none of which ripened normally.

13. *Dates*—The effect of storing processed dates of various grades and unprocessed dates of varying stages of maturity at 32°, 50° to 60°, and 60° to 70° F., in bulk and in packages, has been studied by A. F. Sievers and W. R. Barger (*Techn. Bull. No.* 193, *U.S. Dept. Agric., Washington,* September, 1930). Under the above-mentioned storage conditions inversion of cane sugar progresses according to the temperature. At 32° it is very slight, but at the higher temperatures it is sufficient to make the fruit syrupy in a few months. Partially mature fruit and fruit partially processed may be sucessfully stored at 32° for nine or ten months, whereas the more mature or more fully processed fruit will remain in good condition for not more than five or six months. At the higher temperatures the fruit retained its quality for only a short period. Storage at temperatures sufficiently low to freeze the dates solid appeared to have practical possibilities, especially in connection with the more mature grades of fruit.

14. *Bananas*—The behaviour and diseases of the banana in storage and transport have recently been studied by C. W. Wardlaw and L. P. McGuire (*Publication No.* 36 *of the Empire Marketing Board, London,* January, 1931). For the transport of bananas from the West Indies to England a storage temperature of 54° F. is generally aimed at, since lower temperatures lead to chilling and poor quality in the ripened fruit.

Other Fruits—There is no critical evidence of the influence of temperature on the storage of pomegranates, melons, and other tropical and subtropical fruits.

Vegetables—Cold storage is rarely employed in Great Britain for preserving vegetables, its use for this purpose being chiefly restricted to the less bulky products, such as asparagus. In steamships carrying passengers it is, however, customary to keep the vegetables required as ship's provisions in cold storage, with results that are not always satisfactory.

Very few critical data on the cold storage of vegetables are to be found in the literature. A temperature just above freezing point appears to be the most suitable for the storage of vegetables, most of which are severely damaged or altogether spoiled by actual freezing. In the following table the results of storage trials with certain vegetables carried out by Barker (*Ann. Rpt. Food Invest. Board, London,* p. 39, 1928) in this country and by Plank (*Beih. zur Zeitschr. für die gesamte Kälte-Industrie,* Ser. 3, No. 2, 1927; Ser. 3, No. 3, 1928) in Germany are briefly summarized.

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Life of Vegetables in Cold Storage.

Vegetable.	*Temperature of Storage.*			
	32° *F.*	33° *F.*	35° *F.*	45° *F.*
Peas	4 weeks			
Beans			2-3 weeks	
Cucumbers	3-4 ,,	2-3 weeks		1-1½ weeks
Cabbage lettuce ..	5 ,,			
Tomatoes		(See under	fruits above)	
Asparagus			3-4 weeks	
Cabbages		5 weeks		3 weeks
Cauliflowers		4 ,,		1⅓ ,,
Brussels sprouts ..		1-2 ,,		3 days
Celery		3 ,,		2 weeks
Turnips		5 ,,		
Onions		10 ,,		

According to H. Hasselbring (*Plant Physiol.*, ii., p. 225, 1927) the two principal changes which take place in carrots during storage consist in a conversion of sucrose into reducing sugar, the quantity of which is correspondingly increased; and a transformation of polysaccharides to simple sugars. Since the flavour of carrots is determined largely by their content of sucrose, it is advantageous to retard these changes as much as possible, hence a low storage temperature is to be recommended. M. C. House, P. M. Nelson, and E. S. Haber (*Iowa Agric. Expt. Stn. Res. Bull.* 120, 1930) have shown that after storage for five months at a temperature of 35° to 45° F. the vitamin B content of carrots was not affected.

No doubt owing to their economic importance numerous observations have been made on the injurious effects of chilling temperatures—well above the actual freezing point of the tissues—upon growing crop plants (see J. P. F. Sellschop and S. C. Salmon, *J. Agric. Res.*, xxxvii., p. 315, 1928, for a comprehensive account of this subject). Similar effects have been noticed when such plants are stored or transported at similar temperatures; black leaf speck of crucifers and redheart of cabbage and head lettuce are cases in point.

Potatoes, parsnips, and sugar beets form a group of vegetables characterized by the fact that at low temperatures, in the neighbourhood of zero Centigrade, the starch-sugar equilibrium is shifted, sucrose accumulating in the tissues. This phenomenon, in the case of the potato, was noted by Müller-Thurgau as far back as 1882, and has since been observed in the parsnip by V. R. Boswell, *Univ. Maryland Agric. Expt. Stat. Bull.* 258, p. 61, 1923; in sugar beet by H. W. Wiley, *U.S. Dept. Agric. Bur. Chem., Bull.* 64, 1901; and in sweet potato by H. Hasselbring and L. A. Hawkins, *J. Agric. Res.*, iii., p. 331, 1915. The reverse effect occurs when the roots or tubers are returned to

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higher temperatures, so that within certain limits the sugar content of these vegetables can be controlled at will. But whereas in the case of the parsnip and sugar beet the sweetening is advantageous, the value of the potato, on the other hand, is materially reduced by this change.

Potatoes intended for use as seed are often stored at low temperatures, sprouting of the tubers being retarded in cool storage.

Experiments have been carried out to ascertain the effect of keeping cabbages, cauliflowers, Brussels sprouts, peas, beans, and parsnips in a hard frozen condition, but in all cases the products were found to be unpalatable after thawing and cooking. Parsnips stored at 20° F. break down very rapidly upon removal to ordinary room temperatures and are quite unfit for food. On the other hand, experiments in which the products were only slightly frozen gave good results. At the temperatures used, 26° and 29° F., partial freezing occurs with most vegetables. In the case of tomatoes, cucumbers, and lettuce, which are generally eaten without preliminary cooking, freezing at these temperatures results in severe disorganization of the tissues, and after thawing the texture and appearance are unsatisfactory. For this class of vegetables, therefore, the method is unsuitable, but with other vegetables, such as cabbages, cauliflowers, and Brussels sprouts, the quality of the cooked product is but little affected.

Seeds—Many authors have dealt with the effect upon germination of exposing seeds in the moist condition to low temperatures. The practice of "stratification" of seeds, which is really a process of chilling, is a method of general application for stimulating the germination of the dormant seeds of various plants (W. Kinzel, "Frost und Licht als Beeinflussende Kräfte bei der Samenkeimung, etc.," Stuttgart, 1913; F. V. Colville, *J. Agric. Res.*, xx., p. 151, 1920; L. V. Barton, *J. Forestry,* xxvi., p. 774, 1928). For example, seeds of the bunchberry, *Cornus canadensis*, sown in a greenhouse at a temperature of not less than 55° F. showed no germination in twelve months. These seeds were then subjected to a chilling temperature of 35° to 40° F. for a period of two months, after which they were transferred to the greenhouse (at 55° F.). Within a month all the seeds had germinated.

The chemical and physiological changes occurring in seeds with dormant embryos during after-ripening at low temperatures are described by D. Pack for *Juniperus* (*Bot. Gaz.*, lxxii., p. 139, 1921); by S. H. Eckerson for *Cratægus* (*Bot. Gaz.*, lv., p. 286, 1913); and by H. C. Joseph for species of *Betula* (*Bot. Gaz.*, lxxxvii., p. 127, 1929).

Under the heading Seed, Physiological Predetermination of, full reference is made to the interesting predetermining effects of exposure to low temperature during germination of the seeds of certain winter varieties of cereals.

Hardening of Plants—It has long been known that many plants become more resistant to frost injury after having been kept for a time at a fairly low temperature (38° F. *circa*), but it is only in recent years that the so-called hardening phenomena have been scientifically in-

REFRIGERATION (*Continued*)—

vestigated. The result of a single experiment out of many carried out by Harvey in 1918 (*J. Agric. Res.*, xv., p. 83, 1918) may be quoted. Two lots of young cabbage plants were grown in a warm bed. One lot was transferred to a low temperature, about 38° F., whilst the other was kept at about 70° F. At intervals plants were taken from each of these lots and exposed to severe freezing conditions for half an hour. The plants removed directly from the warm conditions to the freezing conditions were without exception killed, whereas those which had been allowed to harden during five days at 38° F. survived, although they had been exposed to the same degree of frost for the same length of time, and although in this exposure they had been frozen hard.

Harvey afterwards extended the scope of his experiments to a study of the changes in chemical composition which take place during the hardening treatment. He found that the equilibrium between starch, glucose, and sucrose in the non-hardened plants was displaced in the hardened (chilled) plants in the direction of the mono- and disaccharides—that is, in the direction of increased hydrolysis. (See Winter Hardiness and Drought Resistance.)

Other Horticultural and Agricultural Practices for which Refrigeration is Used—Among other agricultural and horticultural practices in which refrigeration has been profitably employed may be mentioned the storage of dry seeds, bulbs, cut flowers, cuttings, and nursery stock, and the chilling for forcing purposes of bulbs, cut flowers, etc. Unfortunately critical data on these points are almost completely lacking. The problem of the optimum temperatures for treating plants or plant organs which are to be forced from dormancy to growth in unusual times of the year opens up a large field of experimentation.

Methods of Storage and Transport—Refrigeration can be supplied to a storage chamber either by the direct expansion of the refrigerant (usually ammonia or carbon dioxide), or by an indirect process in which the refrigerant cools a quantity of brine, and the brine is then used to cool the chamber; the indirect system generally gives a better control, but is necessarily more elaborate and expensive. The refrigerating pipes (whether they contain the refrigerant itself or brine) may be placed inside the chamber on the roof or walls, or may form a "battery" outside the chamber, over which air is circulated by means of a fan. Forced air circulation is fundamental to the second arrangement; it is only incident to the first, and more often than not is dispensed with, reliance being placed on convective air movement to convey heat from the chamber and its contents to the pipes.

The system of grids inside the chamber without air circulation is generally employed in the storage and transport overseas of frozen commodities (meat, butter, etc.); it is also used for the very important overseas carriage of chilled meat where the small chambers and numerous independent brine circuits afford possibilities of very accurate temperature control. The battery system, on the other hand, was designed particularly for the carriage of fruit and other products at temperatures above freezing point, where there is always

REFRIGERATION (*Continued*)—

a difficulty owing to the tendency of overhead pipes to drip moisture, which at lower temperatures would be frozen upon them as snow. The difficulty can be met to some extent by the provision of drip trays, but generally only at the cost of some loss of space and some impedance to convective air movement.

A third system adopted on numerous ships which have occasion at different times to carry both chilled and frozen cargoes (*e.g.*, vessels in the Australasian trade) is to screen off the grids on the sides of the hold when carrying chilled cargoes, and to make of these a sort of battery over which air is circulated by means of a fan, being introduced through apertures in the screens on one side of the hold, and withdrawn through similar apertures in the screens on the other side. The roof grids are then not used at all.

All three systems meet with serious technical difficulties in the attempt to maintain uniform conditions of temperature and humidity in a large and closely packed chamber such as the hold of a ship, which may have a volume of 80,000 cubic ft. and a content of 700 tons of refrigerated produce. Particularly is this the case when, as with fruit, the cargo itself generates heat and evaporates water. The task is still further complicated if the fruit is loaded warm, in which case the refrigerating system has to remove not only the additional " inherent " heat, but the increased amount of heat generated by the fruit at the warm temperature. Bananas are particularly difficult in this respect because of their intense respiratory activity, especially at the relatively high temperature (52° F.) necessary for successful transport. A moment's comparison of this case with another—that of the carriage of frozen meat across the tropics at a low temperature of 10° F., where the difficulty of temperature control is entirely a matter of thermal leakages through the insulation—will serve to illustrate the variety of problems offered to the marine refrigerating engineer.

In land stores the problems are generally much smaller in scale. On the other hand, the requirements as to uniformity of temperature and humidity are often more rigid, since the periods of storage may be longer and nearer the maximum limits for the material considered.

Transport over land involves another set of considerations. For rail transport of chilled or frozen produce a closed insulated van with ice bunkers at either end is the usual vehicle provided. Mechanically refrigerated vans have recently been developed in America and Europe, and to some extent in this country, and particular success is claimed with a small automatically controlled plant employing silica-gel, which is in use in America. Where long unbroken journeys by a whole train are involved, a single large refrigerating plant mounted on a special trunk may be used to supply refrigeration to the whole of the train, but the limitations of this method are obvious.

LITERATURE ON TRANSPORT, ETC.—Food Investigation Special Reports: No 20, " Problems of Apple Transport Overseas "; No. 21, " 'Gas ' Content and Ventilation of Refrigerated Holds "; No. 27, " Temperature Conditions in Refrigerated Holds." A. J. M. Smith, " Heat

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Production and Evaporation as Factors in Cold Storage," *Proc. Brit. Ass. Refrig.*, xxvi., 81-108, 1920. E. A. Griffiths and R. Davies, "Ocean Transport of Fruit," *U. South Africa Dept. Agric. Sci. Bull.* 56., 1926. Hal Williams, "Mechanical Refrigeration," Pitman, London, 1927; various articles in *Refrigerating Engineering*, 1920-1930. *Proceedings 4th and 5th Internat. Congr. of Refrigeration*, 1924 and 1928.

C. W. and A. J. M. S.

RESEARCH, AGRICULTURAL—See various articles under Agriculture; also Agricultural Research and Education in England.

RESPIRATION—The processes taking place in the tissues of the body by which it is enabled to secure the energy necessary for the maintenance of life are, in a great part, those of oxidation. It follows that an animal must be provided with means of supplying to the tissues the oxygen necessary. In all the higher animals, with which alone we shall deal at length, this takes the form of a pulmonary apparatus situated in the thorax, that is, the part of the body cavity above the diaphragm, a muscular wall which separates this cavity into two parts; the lower part or abdomen contains the intestines, etc. The word respiration, meanwhile, is not restricted in its use in any such way, and it is quite legitimate to speak of respiration in connection with the processes of oxygen absorption in insects, fishes, amœbæ, and plants.

The organs of respiration in the higher animals are the lungs and the accessory organs thereof; in a wider sense we may certainly include the heart and bloodvessels throughout the body. The lungs consist of very numerous bunches of minute, exceedingly thin-walled air bladders, not unlike tiny bunches of grapes. These air bladders, called alveoli, despite the thinness of their walls, are plentifully supplied with minute capillary bloodvessels, between which and the air cells of the alveoli is only the thinnest of membranes, through which gaseous diffusion between the blood and the alveolar air can proceed practically unhindered. Air passes in and out of these alveoli by means of minute tubules, called bronchioles, which anastomose, forming wider and wider ducts, communicating eventually with the outside of the lung by a large tube called a bronchus. The two bronchi, one from each lung, join to form the trachea or windpipe communicating with the air through the mouth and nostrils. The chief bloodvessel passing from the heart to the lungs is called the pulmonary artery, and that from the lungs to the heart again the pulmonary vein. Note here an inversion of the usual course, since the pulmonary artery carries venous blood, the pulmonary vein arterial.

Aeration of the lungs is tidal, *i.e.*, the air passes in and out of, not through, the lungs. This tidal flow may be brought about in two ways, either by rhythmic contraction of the diaphragm (abdominal breathing), or by raising of the ribs by the intercostal muscles. Both methods are employed to some extent simultaneously, both in animals and man. In the human subject the first method predominates in the male, the second in the female. It is, therefore, clear that no

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sudden change can take place in the composition of the alveolar air; it is kept in such a state that a steady diffusion of oxygen into the blood takes place, and a similar steady diffusion of carbon dioxide from the blood to the alveolar air. The corpuscles of the blood entering the lung capillaries contain hæmoglobin, which immediately enters into loose combination with the oxygen diffusing in, forming oxyhæmoglobin, and liberating carbon dioxide, which passes out from both corpuscles and plasma to the alveolar air and eventually to the outer air in the tidal surges. The oxygen is again yielded up by the oxyhæmoglobin to the lymph which bathes the tissue cells from the tissue capillaries. In this case, of course, the partial pressure of oxygen is less outside than inside the capillaries, the precise reverse of what is the case in the lung capillaries. It is worthy of note that a similar intake of oxygen to the blood takes place through the skin, though, of course, to a very much smaller extent.

When for any reason oxygen is used up more rapidly in the tissues, as in muscular work, the excess of CO_2 has to be got rid of, and to do so the excreting mechanism must work at a greater rate. Simultaneously, the demand for oxygen goes up, and consequently a more plentiful blood supply and deeper and more rapid breathing are required, and hence results the increase in heart rate, depth and rapidity of breathing, which are a commonplace when any muscular work is undertaken. The controlling mechanism of this change is in the brain, but largely outside voluntary control; it is known as the respiratory centre, and is situated in the bulb. It was for some time thought that excess oxygen tension had an effect on the respiratory centre in reducing breathing entirely comparable to that of carbon dioxide in increasing it. It has been established, however, that the real effect on the respiratory centre is produced by variation in the hydrogen ion concentration, and that it is this that is affected by the carbon dioxide tension. Acid products of metabolism have a similar stimulating effect. For a fuller discussion of this point see K. A. Hasselbalch, *Biochem. Ztsch.*, xlvi., 403, 1912.

The existence of respiration in plants was much disputed in the early part of the nineteenth century; notably Liebig was a profound disbeliever in it. It is now established beyond possibility of doubt that plants respire like animals, using up oxygen and producing carbon dioxide. The process goes on side by side with assimilation (*q.v.*) in sunlight, but whereas only the green parts assimilate, all the cells respire. The plant is able to build up tissues because assimilation is very greatly in excess of respiration. Light has nothing to do with the respiratory processes in plants; they go on as well in the dark, and may be rendered evident by keeping germinating seeds, etc., in an enclosed space in the dark. Under these circumstances the whole of the oxygen in the space may be used up with formation of an equal quantity of carbon dioxide, indicating consumption of carbohydrates. In the case of crassulaceous plants and some fatty seeds the carbon dioxide produced is less than the amount of oxygen used, so that here we have something analogous to the existence of a respiratory

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quotient in animals (see Calorimetry, Animal), and the interpretation is similar.

Deprivation of oxygen has a less serious effect on plants than on animals, as they seem able to live for some time upon the intramolecular oxygen in their tissues.

RHUBARB—See Market Gardening.

RICE—Rice is the most important of the cereals, and forms the food supply of more human beings than are fed by any other cereal. No accurate statistics of world production are available, but in round figures the world acreage is 125 millions with a production of 80 million tons. Of these figures Empire production is some 50 million tons from 80 million acres.

The cultivated plant is referred to a single species, *Oryza sativa* L., of which, however, the varietal forms have never been fully enumerated and certainly exceed a thousand. (For partial enumeration see Copeland, "Rice.") At one extreme lies the "mountain" rices cultivated in the Himalayas under conditions which approximate, especially in the matter of water supply, to those required for the cultivation of other cereals; at the other lie the "deep-water" rices growing in swamps having as much as 5 or 6 ft. of water. In conformity with the economic use of the crop, the grain characters, mainly relative measurements, have been used for varietal classification, while colour, which occurs throughout the plant, has also been used. The inheritance of colour has formed the subject of investigation (Hector, *Mem. Dept. Agric. India, Bot. Series,* vi., 1913, and *ibid.*, xi., 1922; Parnell, *ibid.*, xi., 1922). The inflorescence is a loose panicle, the so-called "seed" or grain consisting of the kernel and four glumes which constitute the "hull." The grain with the "hull" is the "paddy" of commerce, "rice" being the kernel after the removal of the hull and seed coats by the processes of milling and polishing. The flower is normally self-fertilized, but a certain amount of cross-fertilization takes place.

Though its cultivation extends as far north as 40° lat. and in the hills up to 6,000 ft., rice is essentially a tropical plant, and the important areas of production lie in the tropics. Soil plays a relatively unimportant rôle in determining the rice areas, for, with its other requirements satisfied, it will grow on almost any soil capable of producing any crop. The best crops are, however, grown on a rich, smooth, easily worked soil. The conditioning factor is water supply, for rice requires a continuous supply of water, and in this respect differs from all other crops. Where rainfall is not assured, extensive work in levelling, embanking, and canalization is necessary to regulate an artificial supply. The labour that may be expended in this manner is well illustrated in the terraced hillsides of a country like Ceylon. It is this demand for water that makes the retentive capacity of the soil the most important of soil characters, and associates rice with heavy soils. Actually, a rich loam overlying a heavy clay forms ideal rice land. It is this factor, too, that differentiates rice from other cultivated

RICE (*Continued*)—

plants in its relation to humus and fertilizers. The reaction of these under the swamp conditions of rice fields differs much from their reaction under ordinary conditions of cultivation, and associated with this is the preference exhibited by rice for nitrogen in ammoniacal form. (See Nitrification.) Rice responds to organic dressings or green manuring, but it is intolerant of the acid conditions which such substances tend to develop; in their use it is necessary, therefore, to take steps to counteract this tendency (Harrison, *Mem. Dept. Agric. India, Chem. Series*, iii., iv., and v.).

Where rice is grown under inundation, the slight differences of level which result from the care taken in levelling and embanking are reflected not only in the depth of water in which the crop grows, but in the length of the growing season, the higher lands being the last to be flooded and the first to dry out. It is these conditions which have led to the evolution of large numbers of races, mainly distinguished by the length of the growing period, and severally adapted to even a few inches difference of level.

Normally the land is ploughed after the first rains have softened the hard, baked surface, and the soil worked into a fine, even consistency with the plough frequently working under water. On this the seed may be broadcasted, in which case it is soaked for two days, and then left for a further period till sprouted. In this condition it sinks readily, and the young plant secures a hold on the soil with its fine roots which lack root hairs. Commonly, however, the seed is sown in nurseries established where an early assured water supply is available and the seedlings transplanted. In the Bombay Presidency is found the practice of burning the seed-bed before sowing (Mann, *Mem. Dept. Agric. India, Chem. Series*, viii., 1912).

Rice is subject to a number of insect pests, but, considering the vast areas grown in unbroken sheets, they have not the importance that might be expected. Among the more important are a nematode, (*Tylenchus*), which causes the *Ufra* disease of India; a bug (*Leptochorisa*) and a borer (*Schœnobius*), both found widely distributed throughout the East.

Of the world's production of rice some 64 per cent. is of Empire origin, and of this all but an insignificant portion is grown in the East and especially in India, to which the following figures apply:

	Acres (Millions).	*Production (Million Tons).*
Bengal	21·0	8·0
Bihar	16·5	8·5
Madras	11·0	5·5
Burma	11·0	5·0
United Provinces	7·0	2·5
Central Provinces	5·0	1·5
Assam	4·0	1·5
Rest	5·0	2·0

The centre of rice production, as these figures show, is Bengal and the neighbouring provinces of Assam and Bihar. In this tract, though

RICE (*Continued*)—

the main crop is dependent on the rains and the associated floods brought down by the Ganges and Brahmaputra, the conditions are such that rice is grown at almost any season and under an infinite variety of cultural conditions. With this range of conditions is associated a large and indefinite number of varieties mainly associated with the depth of water and season of cultivation. As is commonly the case with the crops grown by peasants in the tropics, the varieties recognized are not botanically pure, and considerable improvement can be effected by the isolation and multiplication of promising races. Of such a kind is the *indrasail* rice now widely grown in Lower Bengal and Assam (Hector, *Agric. J. of India*, xii., 1917). There are three main rices, recognized by their season of growth: *Aman* rice is sown in May, and reaped in November or December. Generally speaking, it is a deep-water rice, and, where transplanted, it must be established before the floods. *Aus* rice is planted in April or May, and reaped in July or September. It is a shallow-water rice which must be reaped before the flood where this exceeds 2 ft. *Boro* rice is sown after the flood, in October, and reaped in April or May, and is usually transplanted. Numerous variations on these major systems of cultivation are also found (Watt, "The Commercial Products of India," and Sherrard, *Bull.* 96, *Agric. Res. Inst.*, Pusa, 1920).

In passing west up the Gangetic plain the flooded areas become less common. Also temperature sets a limit to the period of growth. The rice season is consequently restricted. Rice is here grown as a rains crop, with embankments made to hold up the water. On the edges of jheels (swamps) where water remains after the rains have ceased, and in other localities where water can be conserved, rice is transplanted; elsewhere it is broadcasted. Here, too, many of the races, notably "sathi," are of short season, and capable of ripening a crop under conditions differing but little from other rains crops, and, in this particular, form a link with the "mountain" races of the Himalayas already mentioned.

In Madras the conditions under which rice is grown are as varied as in Bengal, and in certain tracts, as South Kanara, rice is the staple crop, and as many as three crops may be raised on the same land in one year. Rice cultivation is here developed to a fine art, and broadcasting is rarely practised.

On the uplands of Central India this range of systems is not found, since the rice season is confined to the rainy season. Though the area under rice is large, little skill is exhibited in cultivation, and considerable improvement has been effected by the simple process of introducing transplantation in place of broadcasting.

Burma, though it does not head the list of rice-producing provinces, is in one sense the most important, inasmuch as it is the main exporting country of the world, and exports some 5 cwts. per head of population. Though a certain amount is grown in the northern wet zone, the main rice area is the deltas of the Irrawadi and other rivers. The crop is almost entirely rain-fed, and, as such, its cultivation is limited to the rainy season. There is not, thus, the wide range of

RICE (*Continued*)—

systems found in Bengal, though the same range of variation, associated with depth of water, is found. Considerable improvement in the crop has been effected by selection from the mixed races commonly found (Hendry, "Tropical Agriculture," v., 1928).

In the East, rice is also grown in Malaya (Jack, *Malayan Agric. J.*, xi., 1923; Tempany, *ibid.*, xviii., 1930; Sands, *ibid.*, xviii., 1930) and Ceylon, but both are importing countries. The production in Africa is negligible, while in the West Indies a considerable production is associated with the system of indentured Indian labour which has left an established Indian colony, especially in Trinidad and British Guiana. The West Indies as a unit, however, is not self-sufficing in the matter of rice production, though British Guiana produces more than her own requirements, and has immense possibilities as a rice area.

No account of rice would be complete without a reference to the connection which recent work has shown to exist between the use of over-milled rice and Beriberi (*Polyneuritis endemica*). The history of the unravelling of this connexion first determined by Eijkman in 1897, of the discovery of vitamins and their function and, through this, of the various deficiency diseases, forms one of the romances of medical science (*Medical Research Council, Special Report*, xxxviii., 1924). As has happened in the case of more than one discovery of far-reaching importance, here, too, the connexion was determined independently by Hose working in Sarawak (Hose, "A Jungle-wallah at Large"). In the process of milling and polishing, both the entire pericarp and the germ, the seat of the water-soluble vitamin B, are removed, and rice thus prepared and forming the staple food of whole populations in the East forms a dietary definitely deficient in this essential vitamin. Just as the means of combating malaria have been found to be the control of the Anopheles mosquito, so a prophylactic means of controlling Beriberi has been provided by this work. (For the chemical composition of rice and its value for stock feeding, see Foods and Feeding, and Feeding Stuffs.)

H. M. L.

RICE GRASS (*Spartina Townsendii*) is a tall, deep-rooted grass inhabiting maritime muds, and has been used with remarkable success in reclaiming mud flats occurring at the estuaries of several rivers in the British Isles. It has also been exported to Holland, Germany, and places in the Antipodes. A full description of the grass, together with detailed account of various plantings in situations in this country and on the Continent, is given in "Rice Grass, its Economic Possibilities," *Min. of Agric. and Fish.*, Misc. Publication No. 66 (F. W. Oliver, J. Bryce, and F. Knowles). In this publication the results of the determinations of the composition and of the nutritive value of this grass are also discussed.

RIDGE—Ridge or rig is sometimes used in the same sense as "balk" (see Balk)—that is, to mean a "set up" drill or row to be used for planting. More correctly, however, ridge is the name given in ploughing to all the land between any two open furrows.

RIDGE (*Continued*)—

When a piece of ground has been ploughed it is left in ridges, each of which are the same width. Ridges are made up of different parts—furrow slices laid upon and parallel to one another by the going and returning of the plough from one end of the ridge to the other. The middle line of the ridge is called the crown; the two sides, the flanks; the openings between the ridges, the open furrows; the edges of the furrow slices, next the open furrows, the furrow brows; and the last furrows, which are small, are the mould or lint-end furrows.

Ridges vary in width from 7 to 14 ft., and may be even wider. The variation in width is occasioned partly by soil and climate, and partly by local custom. (See Ploughing.)

ROCK PHOSPHATE—See Fertilizers.

ROCK SALT—A native form of sodium chloride (*q.v.*) containing about 5 per cent. of marl.

ROTATIONS—The advantages of the rotation of crops have been appreciated from very early times. Several of the Roman writers on husbandry discuss the subject at length, and show a clear understanding of the main principles. They enumerate the crops specially liable to exhaust the soil, and recommend that these should not be too frequently repeated; they recognize (while they do not explain) the fertilizing effect of leguminous crops; and they point out that the frequency of fallows should depend on the natural fertility of the soil. There are still, however, many parts of the world where true rotations are not in use. In many areas of Asia and Africa the normal practice is to clear a block of jungle or scrub, to crop this until soil exhaustion or the accumulation of pests makes its cultivation unprofitable, and then to abandon it for a time to nature. In the meantime another block is taken into tillage. There is reason to believe that this system of shifting cultivation, often known by its Ceylon name of "chena," was that first adopted by all primitive peoples. It tends to persist wherever land is plentiful in proportion to the population, although under certain circumstances the clearing and breaking up may be so costly in labour that it becomes more economical to maintain the fertility of a permanent arable area.

Traces of this primitive system remained in Britain until quite recent times. In Scotland it remained, until far on in the eighteenth century, the normal farming scheme for the so-called outfields. These lands, which constituted the poorer or outlying portions of the arable area of the farm, were alternately cropped to exhaustion with oats, and abandoned for indefinite periods to wild grass and weeds. The Anglo-Saxons, however, had advanced beyond this stage before their settlement in Britain, and had adopted a permanent division of their land into arable, meadow, and common pasture. Thus, in the whole central area of England, where the Saxons introduced their own agricultural practice (this area stretched from Durham to the Isle of Wight, and from Cambridge to the Severn Valley; it embraced nearly half of England and Wales), fixed rotations were

ROTATIONS (*Continued*)—

established in early Saxon times. On the poorer and thinner land a two-field system was usually followed, one field being tilled and sown with cereals and pulse crops, while the other was allowed to lie fallow. On the better soils a three-field system was either adopted from the outset, or was soon substituted for the other. This was characterized by the succession, (1) winter corn, (2) spring corn, and (3) fallow, the corn being chiefly cereals, but including generally a proportion of peas and beans. In Scotland, apart from the outfields already mentioned, there was a proportion of infield or croft land which was cropped every year with cereals or pulse in a definite order of succession, which order varied from one district to another. With regard to the other areas (Cornwall and Devon, Wales, the north-west, Kent and East Anglia) it is impossible to generalize except to say that the two- or three-field system was never established, and that rotations were varied and not rigidly fixed by custom.

A certain amount of progress in regard to rotations occurred quite early, at all events long before the great enclosures of the eighteenth century. Thus, on some Midland manors there was a change-over from a two-field to a four-field arrangement, the succession becoming (1) winter cereals, (2) peas and beans, (3) spring cereals, and (4) fallow. This had the double advantage of introducing a leguminous crop as a regular feature and of reducing the proportion of uncropped land. It was not, however, until after the new crops (turnips and other roots, potatoes, clover, and sown grasses) came into general cultivation that there was any widespread departure from the old cropping schemes. Our first modern rotation was the Norfolk four-course, which (stated in its most general terms) is (1) winter cereal, (2) roots, (3) spring cereal and (4) clover or mixed "seeds." This serves as well as any other to illustrate the objects to be arrived at, and the principles to be observed, in devising rotations. The more important of these are as follows:

I. **Weed Control**—The mere alternation of crops on a given piece of ground has a beneficial effect in preventing the multiplication of weeds. Charlock is much less troublesome in winter than in spring corn; common couch competes successfully with cereals, but tends to be suppressed in a close sward of temporary grass. Certain crops like late potatoes and the common sorts of silage mixtures exert a useful weed-smothering influence. Further control must be sought by the introduction of crops with a growing season short enough to permit of partial or rag fallows; by the introduction of summer tilled or fallow crops; and (generally as a last resort) by bare fallowing. In the Norfolk rotation active cleaning operations are generally begun on the winter corn stubbles, and are continued during the spring and summer of the following year when the land is under roots. If these measures are insufficient a bastard-fallow is introduced at the cost of the second cut of clover. (See Weeds.)

II. **Control of Plant Diseases and Pests**—It is easily to be understood that such fungi and insect pests as confine their attacks to particular

ROTATIONS (*Continued*)—

genera or orders may become very troublesome when their host plants are continuously grown on the same land, and may on the contrary be kept under control by a carefully planned succession of crops. There are other and still obscure forms of crop "sickness" that can be prevented by arranging for a certain minimum interval between successive crops of the same species. In the past, the Norfolk four-course scheme has often required modification on account of the occurrence of "Finger and Toe" in the crucifers and "Clover Sickness" (Sclerotinia, Eelworm, etc.) in leguminous crops. (See Diseases of Cereals, under Wheat.)

III. **The Maintenance of Fertility**—The physical fertility of many soils—their workability and capacity for retaining moisture—is closely dependent on their humus content. This dependence is greatest in the case of the more extreme types—sands, heavy clays, and very shallow soils; it is least on deep medium loams with retentive subsoils. Accordingly more or less attention must be given to the supply of organic matter. In this connexion also the rate of wastage of the organic fraction must be borne in mind. This is highest under a moist, warm, equable climate and where the soil is well aerated, either owing to its frequent tillage or to its natural texture; it is least under "continental" climatic conditions, and where the soil is left undisturbed. The ordinary measures for the upkeep of the humus content of the soil are the inclusion of forage crops, temporary leys, or green manuring crops in the cropping scheme. (See Soil Colloids and Humus.)

The inclusion of leguminous crops at regular intervals effects what may be an important saving in the manure bill. Under the more intensive systems, however, the importance of leguminous crops, as such, is tending to decline with the increasing supplies of nitrogenous fertilizers.

IV. **Economy of Labour**—In the past one of the chief aims of farm organization has been to keep the labour requirement of the farm (both of man and horse labour) as nearly constant as possible throughout the year. This could be achieved only by growing a variety of crops with different seed times, harvest periods, etc. This consideration has tended to favour the more complicated cropping schemes and to prevent the introduction of specialist systems, and the mass production methods of the manufacturing industries. It is worthy of note, however, that the increasing mobility of human labour on the one hand, and the substitution of mechanical power for horses on the other, are opening up new possibilities. In the new countries especially, agricultural development is tending in the direction of a simple, specialist type of rotation based on a mobile labour force and a large reserve of power machinery.

V. **Local and Special Circumstances**—The soil and climate of the locality, the vicinity of markets, the wage rate, the supply of casual labour, must necessarily affect the choice of crops and the whole farming scheme. These questions are dealt with under "Farming Systems."

The rotations at present in use in Britain are almost infinite in

ROTATIONS (*Continued*)—

number, and no detailed discussion of particular examples can be attempted. A broad distinction can, however, be made between those of the north and west on the one hand and those of the south and east on the other, the line of demarcation running roughly from Durham to Somerset.

In the former area the usual system is one of alternate husbandry, the arable land being laid away to grass for a period of years and again broken up for cropping. A typical rotation of this kind would be (1) oats, (2) roots, (3) oats or barley, and (4) seeds ley, lying for perhaps three years. At the one extreme, for example, in upland sheep districts, the duration of the ley is indefinite and arable cultivation is reduced to the minimum necessary for the renewal of the sward. At the other extreme, for example, in the best arable districts of eastern Scotland, the ley is reduced to two years or even to one, and the number of arable crops is increased. A common rotation of this type is (1) oats, (2) potatoes, (3) wheat, (4) roots, (5) barley, (6) seeds ley for one or two years.

In the south-eastern area the more usual system is to make a permanent division between grass and arable, and to plough the latter area at least three years out of four. The difference between this practice and the foregoing can be explained partly on historical grounds, but is due in part also to the greater difficulty of establishing grass seeds in the hotter and drier districts. On most of the lighter soils, where roots were found to be fairly reliable, the Norfolk four-course rotation, or some slight modification of it, was that originally adopted. In recent years, however, increasing labour costs have led to a marked diminution of the root area, and there are now comparatively few districts where the land comes under turnips, swedes, or mangolds every fourth year. In certain cases the potato or sugar-beet crop has been substituted, and the old proportion of 25 per cent. of fallow crops has thus been maintained. In other circumstances it has been found possible to increase the cereal area and still keep the land clean and in good heart. This has been attained partly by the increased use of artificial manures and partly by the use of the tractor in stubble cleaning operations. In any case it is now very common, in the more purely arable districts, to find three acres of corn for each acre of roots or fallow. It is also true that, with the recent improvements in grass seed mixtures, the longer ley is tending to creep into the farming of the south-east.

Another of the classical rotations which deserves mention is the Wiltshire, a four-year system introducing catch crops as a regular feature. In essence it consists of growing two cereal crops in succession and following with three folding crops in the remaining two years. This rotation is associated with arable sheep farming, but it is tending to give way to others with a lower labour requirement.

The degree of adherence to a fixed cropping scheme that is possible or desirable varies a great deal. Where a large permanent herd or flock is maintained a rather strict rotation is desirable, in order to ensure a regular supply of home-grown foods; where only a "flying"

ROTATIONS (*Continued*)—

stock is kept more latitude is allowable. Again, on well-drained sands and loams a regular succession of crops can be planned with the reasonable assurance of its practicability in most seasons, whereas on wet or heavy land the farmer is bound to be an opportunist; his system in extreme cases amounts to planting on the land that happens to be clean as much winter corn as possible, with spring corn on the rest. The foul land is put under roots as far as practicable, and the remainder is bare fallowed. J. A. S. W.

RUBBER—The material rubber is a natural plant product of which the essential substance is a hydrocarbon, caoutchouc, together with variable amounts of resinous and protein substances derived from the plant and a like variable amount of foreign adulterants small in quantity in the plantation, but considerable in the wild, product. It is obtained by the coagulation of the latex drawn from various trees of tropical and, to a small extent, subtropical habitat. The principal rubber-producing plants belong to one of the natural orders *Euphorbiaceæ*, *Urticaceæ*, and *Apocynaceæ*. A few, yielding a product of small commercial importance, belong to the *Asclepiadaceæ*, while one, *Parthenium argentatum* A. Gray, of Mexico, belongs to the Natural Order *Compositæ*. The more important species are:

Euphorbiaceæ—(1) *Hevea brasiliensis* Müll. Arg. This is the Para rubber tree found wild in the Amazon valley and in recent years cultivated in many countries, especially Ceylon, Malaya, and the Dutch East Indies. This tree dominates all others as a source of commercial rubber. The plantations of the East owe their origin to Sir Henry Wickham, who, in 1876, conveyed a supply of seed to Kew, whence plants were despatched to the East. The practical problems of rubber production centre on this Eastern industry. Other species of Hevea also yield rubber (Huber, Essao d'uma Synopse das Especies do Genero Hevea sobos pontos de vista Systematico e Geographico).

(2) *Manihot glaziovii* Müll. Arg. This plant is a native of north-east Brazil, especially of the Ceara Province, whence the name Ceara rubber. Here again this is the most important of the species of this genus which yield rubber.

(3) *Sapium* sp. These trees are found wild along the northern stretch of South America, from the Guianas, through Venezuela to Colombia.

Urticaceæ—(4) *Castilloa elastica* Cerv. The tree is a native of Mexico and Central America. The tree has been widely planted, but has proved uneconomic as a plantation crop in competition with Hevea.

(5) *Ficus elastica* Roxb. This tree is native to Assam. At one time planted in the East, it has given place to Hevea. Other species of ficus, as *F. vogelii* Miq., a native of West Africa, also yield rubber.

Apocynaceæ—(6) *Funtumia elastica* Stapf. This tree is widely distributed in north tropical Africa. The product is collected from the wild tree.

RUBBER (*Continued*)—

(7) *Landolphia* spp., *Clitandra* spp., and *Carpodinus* spp. These three genera form a group of Apocynaceous vines native to the tropical forests of Africa. Rubber is collected from the wild trees. India and America also possess representatives of rubber-yielding Apocynaceous vines.

Asclepiadaceæ—(8) *Cryptostegia* spp. The most important species is *C. grandiflora* R. Br., a native of Madagascar, Reunion, and India, and an introduction into Mexico and the Bahamas.

With the rapid development of the cultivation of Hevea in the East all other sources of supply of rubber have become of small importance, and the agricultural problems are, in practice, confined to Hevea, which alone is considered below. How rapid has been this extension the following table indicates:

	1900.	1929.
	Tons.	Tons.
Malaya		453,468
Ceylon		80,639
Dutch East Indies	4	256,386
Rest (plantation)		45,304
Total (plantation)	4	835,797
Brazil	26,750	22,598
Rest (wild)	27,136	5,015
Grand total	53,890	863,410

In fact, the demand for rubber has expanded with a rapidity that has forced an extension of cultivation which has paid little attention to the requirements of the plant or even to the nature of the plant itself. A further difficulty arises from the fact that the plant takes some four to seven years to come into bearing. This difficulty, of forecasting demand so far in advance, has led to wide maladjustments between supply and demand. Intervals of high prices due to short supply have stimulated the planting up of wide areas which, in their turn, have, on reaching maturity, led to a slump from over-production. The original cultivation of Hevea in the East was on a plantation basis, but in more recent years a large area has been planted up by small native holders in the Dutch East Indies. Unlike many vegetable products, the crude native product is capable of cheap refinement, and, consequently, the cheap native production enters into direct competition with the output of the plantations. Without a further large increase in demand, which is hardly now in sight, the plantation industry can only survive by a stringent reduction of the costs of production. It is this economic aspect that dominates the situation of to-day and is forcing attention to the agricultural aspects, too long neglected, of the crop.

The latex from which rubber is obtained by coagulation is drawn from the tree by incisions on the stem a few feet above the ground. In Hevea the latex is contained in vessels, formed by the fusion of rows of cells, mainly situated in the cortex (Fitting, " Beihefte zum Tropenpflanzer,"

RUBBER (*Continued*)—

1909). For successful growth the tree requires a suitable climate and adequate rainfall in the sense that the natural habitat of the tree is the tropical rains forest. The nature of the soil is of minor importance provided the extremes of sand and clays are avoided and provided the site is well drained. This latter fact was hardly sufficiently appreciated in the early days when the known localities of its growth were the lowlands approached from the Amazon.

The culture of the tree offers little difficulty that ordinary care cannot overcome. The young plants are usually raised in nurseries and planted out in prepared holes amply supplied with humus. In early plantings the trees were undoubtedly set too close, and a distance of 20 by 20 ft., giving 100 trees per acre, is a full allowance. In planting up freshly cleared jungle the natural humus is adequate, but, with clean cultivation, the supply rapidly diminishes and trouble arises through erosion, lack of aeration, and deficiency of nitrogen. On sloping ground, where erosion occurs, it may be checked by a process of silt-pitting, or it may be prevented by the use of cover crops, a practice which is becoming widely adopted. Manuring is so closely interlinked with the character of the particular soil that no general practice can be laid down. In certain areas of the Dutch East Indies with sandy soil a clear response has been obtained to nitrogenous manures (Grantham, *Arch. v. d. Rubbercultuur*, 1924 and 1927), but a like response has not been obtained elsewhere, and the nitrogen requirement is usually adequately provided by control of the natural sources of humus within the plantation (Haines, *Mal. Agric. J.*, xviii., 5, 1930). Loss of vigour with a resultant fall in yield arises from many causes, of which the three mentioned are the main, and the basis of successful production rests on the quick ascertainment of any loss of vigour and the determination of the cause. It is a local problem which must be solved in each case.

vessels, but no sure method of identification has been found (Sanderson and Sutcliffe, *Q. J. Rubber Research Inst. of Malaya*, i., 1, 1929).

The inflorescence of the Hevea tree is a panicle bearing unisexual flowers, the terminal being pistillate and the lateral staminate. The flower appears to be insect fertilized and only to a very slight extent self-fertile, a sterility which appears to extend to different trees, (Maas, *Arch. v. d. Rubbercultuur*, iii., 1919; Morris, *Q. J. Rubber Research Institute of Malaya*, i., 3, 1929). It follows that the Hevea population of cultivation is of very mixed ancestry, and it is not surprising, therefore, to find a wide range of variation in yielding capacity of different trees. Costs can materially be reduced through the elimination of low yielders, and, in this respect, the rubber industry is faced with a problem comparable to that found in Cacao (*q.v.*). Huesser has investigated the yield of the F_1 progeny of known parents, and has found a definite inheritance of high-yielding capacity, but the coefficient of variation between sister plants has a wide range (between 34·5 and 19·0) (Huesser, *Arch. v. d. Rubbercultuur*, xiii., 1929). The

RUBBER (*Continued*)—

capacity for transmitting high yield, however, appears to be limited to certain plants, and the prospect of raising any adequate supply of seed of known parentage hardly offers a practical solution of the immediate problem with which the industry is faced.

It is fortunate, however, that, again as with Cacao, the tree is readily propagated by budding. The technique of budding is well understood, and the work of raising clones of high-yielding scions is proceeding rapidly. Budding material can, with suitable precautions, be transported over considerable distances, and bud wood now passes freely throughout the East (Mann, *Q. J. Rubber Research Inst. Malaya*, i., 4, 1929). It would appear, however, that the parent trees do not invariably hand down their high-yielding qualities, and the only sure test of a tree is the actual measurement of the yielding capacity of the budded offspring (Taylor, *Trop. Agriculturist*, 1926). The interaction between stock and scion requires further investigation.

The direct response of the plant to unfavourable conditions is scarcely measurable. The loss of vigour which is the result of these conditions renders the tree susceptible to disease, which thus becomes the immediate cause for diminished yields. Disease takes no small toll, and not the least of these originate at the root. The most serious root disease is *Fomes lignosus*, Klotzsch. This widely distributed fungus most commonly attacks rubber planted on new lands or planted-up tea and cacao estates where the stumps of former trees have not been rooted up. These stumps form the medium on which the spores germinate and from which the mycelium spreads by contact to rubber. The only preventive is the removal of all stumps capable of harbouring the disease, and the only cure is the isolation by trenching of the diseased tree with its neighbours and the eradication of all diseased material, including the lateral roots. Other root diseases are *Fomes lamaoensis* Murr. (Brown Root disease), *F. pseudo-ferreus*, Wakefield (Wet Rot), *Poria hypobrunnea* Petch (Red Root disease), *Ustulina zonata* Lév., and *Sphaerostilbe repens* R. Br. Accounts of these as well as of other diseases of the rubber tree are given by Petch ("Diseases and Pests of the Rubber Tree," 1921).

The leaf is attacked by numerous fungi, but few, excluding those responsible for a secondary leaf fall, do serious damage. Secondary leaf fall is the result of attack by *Phytophthera* spp., especially *P. palmivora* Butl.; *P. meadii* McRae, and *P. heveæ* Thompson. These widespread and omnivorous fungi develop on the fruit, and thence spread to the young leaves causing them to fall. The claret-coloured canker of the tapping surface is also due to the attack of *Phytophthera* (Beeley, "Fungi and Diseases of the Tapping Panel," *Q. J. Rubber Research Inst. Malaya*, i., 4, 1929). *Glœosporium alborubrum* Petch is also responsible for causing Secondary Leaf Fall, but in recent years a cause of much damage through Secondary Leaf Fall is *Oidium heveæ* Steinm. The attack of this fungus, which appears to have transferred its attention to rubber from some local indigenous plant, is closely associated with the climatic conditions (Sanderson, *Q. J. Rubber Research Inst. Malaya*, ii., 1, 1930).

RUBBER (*Continued*)—

Dieback, where the tree begins to die back from the apex or terminal laterals, is a symptom of various diseases. The fungus most commonly associated with disease is *Botryodiplodia theobromæ* Petch, and, where this is present, the progress of the disease is very rapid Fundamentally, however, the disease is merely an outward expression of physiological ill-health.

Of non-parasitic diseases the most important is Brown Bast, of which the first indication is that the tapping cut goes dry and the cortical tissues become stained a brown colour. In bad cases secondary growth occurs in the cortical tissues, and the bark becomes irregular and useless for tapping purposes. The cause is not fully unravelled. but there is a clear association between the disease and high-yielding trees (Sharples and Lambourne, *Mal. Agric. J.*, 1924). The disease has been investigated by Rands (*Med. van het voor Plant.*, 47 and 49, 1921) and Rhodes (*Q. J. Rubber Research Inst. Malaya,* ii., 1, 1930). It appears to be a reaction of the plant similar to the wood-healing of fruit trees. A deposition of wood gum in the cells bordering on those injured by the cut is followed by a development of meristematic activity which, in severe cases, may give rise to a secondary cambium in the cortex from which arise those nodular growths which render the bark unsuitable for further tapping.

For a detailed account of cultivation see Wright, "*Hevea Braziliensis* or Para Rubber," 1912. H. M. L.

RUST (in Cereals)—*Puccinia* spp. See Diseases of Cereals, under Wheat; Seed, Transmission of Plant Disease by; and Wheat.

RYE—Although this is one of the most important cereal crops grown on the Continent, where the acreage in 1929 was 42 million acres, and also in America, where four and a quarter million acres are grown annually, the area devoted to rye in the British Isles is in the neighbourhood of 40,000 acres only, per annum. In Germany, Russia, Norway, Sweden, and Denmark, rye is used very largely for producing bread-corn, the flour of which is made into black bread.

In the British Isles small areas of this crop are found in most counties, but those with the largest acreages are Suffolk, Norfolk, Lincoln (Lindsey), Nottingham, Hampshire, and the East and West Ridings of Yorkshire.

Utilization of the Crop—In chemical composition, rye grain is similar to wheat, and in the British Isles it is utilized for stock-feeding in addition to, or in substitution of, the other cereals. (See Feeding Stuffs.)

Apart from the grain, the crop fulfils a useful function as green fodder, especially for sheep, in the early months of the year. About February and March the plants have usually attained their maximum vegetative development before running into shoots, and at this time sheep may be run over the crop. The early " bite," coming at a time when green feed is scarce, is greatly valued, and the amount of grain subsequently produced is not reduced in quantity. This method of

RYE (*Continued*)—

treatment, which appears to have come into general use about 1843, furnishes a reason for the continued cultivation of rye in this country which the grain production alone would scarcely justify.

Rye is also utilized in forage mixtures grown for making into silage. (See Ensilage.)

Varieties—A very striking feature of this cereal is its extremely homogeneous character: it is practically represented by one variety characterized by yellow, short-awned ears—*Secale cereale* L. var. *vulgare* Körn.

A further interesting character, and one that distinguishes it from the other cereals, wheat, barley, and oats, which are normally self-fertilized, is that it is mainly cross-fertilized.

The inflorescence of rye is a spike, or spike-like. The spikelets usually consist of three florets, the whole being contained by a pair of narrow, long, lanceolate glumes, closely resembling those found in varieties of commonly cultivated barleys. The outer two florets are usually fertile, whilst the third, or innermost floret, is sterile. The outer paleæ of the two fertile florets are keeled down to the point of attachment to the rachis, and are extended aerially into a straight awn. The keel and the two edges of the paleæ are covered with strong, outwardly directed setæ. The grain, when ripe, is usually greyish-brown and naked, as in wheat; it may be long and narrow, long and broader towards the base, short and narrow, and short and broader. In all cases it is pointed towards the germ end.

The position of the spikelet relative to the rachis resembles the arrangement found in wheat, *i.e.*, the edges of one side of the paleæ are opposed to a broad side of the rachis.

Common cultivated rye is usually considered to have arisen from a wild prototype, *Secale montanum* Guss.—a perennial species found in elevated regions in a great many south and south-eastern European countries and the adjoining Asiatic countries. In recent years, however, a botanical survey of some of these regions carried out by members of the Institute of Applied Botany and Plant Breeding, Leningrad, has revealed an extensive series of forms of rye not described before. Some of these differ from the cultivated rye of Europe in the colour of the ear, and in various vegetative and morphological characters, but more interesting still, others exhibit a brittle rachis, and are thus homologous to similar forms of wheat, barley, and oats possessing an identical means of natural seed dispersion. Many of the new forms, now described for the first time, are found as weeds in winter wheat, and are winter ryes, whilst forms of spring ryes occur in crops of spring cereals. It was also observed that many of the newly described forms exist as cultivated crops at altitudes and under conditions inimical to wheat and barley (N. I. Vavilov, "Studies on the Origin of Cultivated Plants," 1926, and V. Antropov, *Supplement* 36, *Inst. Econ. Bot. and Plant Breeding*, Leningrad, 1929).

It is probable, therefore, that these weed ryes rather than the perennial species, *Secale montanum* Guss., are the progenitors of the

RYE (*Continued*)—

cultivated European rye (A. A. Grossheim, " A New Variety of Wild Mountain Rye in Transcaucasia," *Bull. of Econ. Bot. and Plant Breeding*, Leningrad, vol. xiii., 1922).

Soil and Cultivation—Rye is undoubtedly the one cereal crop that can be grown on light, sandy soil with a reasonable degree of reliability. The winter forms, in addition, possess a higher degree of winter hardiness than any variety of the other cereals, on the class of land described. It is also claimed that rye can sustain acid conditions of the soil better than barley and wheat.

The provision of sheep feed, adaptation to sandy soil, and a high degree of winter hardiness, indicate the position this cereal can most usefully occupy in the rural economy of this country.

Winter rye, which is the form most generally utilized in the British Isles, is usually drilled in September or early October, the manner of drilling and the quantity of seed used being similar to that adopted for wheat.

The crop is early in ripening, and the yield of grain is in the neighbourhood of 14-15 cwts. per acre. The straw is long, fine, and resilient, but of little value for stock-feeding. On the farm, consequently, it is used principally for thatching and similar purposes, whilst in some districts it is utilized in the manufacture of straw goods.

The few summer ryes available are characterized by high tillering capacity and earliness in ripening, but their grain-yielding potentialities are not so great as those of the winter sorts. H. H.

SAFFRON—The dried stigmas of *Crocus sativus*. An old herbal and dye cultivated largely in times gone by round Histon in Cambridgeshire and in the neighbourhood of Saffron Walden. Its chief home is the Mediterranean, Persia, Kashmir, and China. It was used in ancient Greece in the preparation of a perfumed salve, but nowadays its cultivation is practically confined to the West Country, where saffron cake is esteemed. It is said to be a cure for an obscure skin disease of white pigs caused by eating buckwheat. It is sold in two forms: *cake saffron*, in which the stigmas and styles are pounded up together to form a cake; and *hay saffron*, which is the dried stigmas alone.

SAGE—See Herbs, under Market Gardening.

SAINFOIN—According to most agricultural writers sainfoin was introduced into this country from the Continent about the middle of the seventeenth century. Percival (" Agricultural Botany," Duckworth, London) suggests that the plant is probably indigenous to the dry chalky soils of the midlands and south of England.

Its virtues were extolled as early as 1700 by Edward Lisle in his " Observations in Husbandry," also by Tull, his contemporary, and by Aubrey before them. These writers refer to the crop as " French grass " or " saint foin," and all of them dilate in the highest terms on the value of sainfoin as a forage crop.

It cannot be denied that in the eastern and southern counties of

SAINFOIN (*Continued*)—

England sainfoin is one of our most important leguminous crops, and as such it has not received the notice and advancement from modern writers that its good qualities merit.

There is a general impression that sainfoin is suited only for rather shallow and dry soils on the Chalk and Limestone formations. An expression of opinion of this kind cannot be too strongly resisted, as the crop will thrive under a wide variety of conditions both of soil and climate. The main considerations are that the soil must be well drained, free from springs, well supplied with lime, and the water-table must be low.

The crop can be grown successfully as far north as the Humber and as far west as Gloucestershire. Nevertheless, it is true to say that the crop is chiefly cultivated on the thin, chalky soils in the east and south-east of England, but it could be extended profitably to many of the boulder clays which are now being laid down to indifferent permanent grass.

Varieties—Originally there was only one variety of sainfoin cultivated in Great Britain, viz., *Onobrychis sativa*, or Common Sainfoin.

Later, another and, in many respects, a better variety was introduced—*Onobrychis sativa* var. *bifera*, the Giant or Double-Cut Sainfoin, see Thomas Hine, "On the Giant Sainfoin," *J.R.A.S.E.*, vol. x., 1849. This variety is the one more commonly cultivated on the lighter class of soils, where it is sown for either one or two years, but more usually for one year only. It takes the place of the ordinary clover crop in the rotation. The first crop is usually mown for hay, and the second is either folded with sheep or saved for seed.

The Common sainfoin is a more permanent variety, and, provided weeds can be kept in check, it may be left down for seven years or even longer. This variety is more commonly found on heavy soils where it is customary to "lay down" a sainfoin ley for a number of years, or for as long as such weeds as slender foxtail (*Alopecurus agrestis*) and couch grass (*Agropyrum repens*) can be kept under control. It has been found that 1 lb. per acre of wild white clover seed sown at the time of drilling will quickly cover the ground between the rows, and so prevent the spread of weeds which eventually choke the sainfoin. There is also the additional advantage of greatly increasing the fertility of the soil, a well-known and valuable character of wild white clover.

In some parts of the country, particularly Kent, sainfoin is sown in mixtures along with red clover, crimson clover, etc. Sainfoin does best when sown as a pure crop, and there is no advantage gained in trying to make it a "mixture" plant.

Seeding—Sainfoin is usually sown with barley as a "nurse" crop on the lighter, and with wheat on the heavier soils. In the dry eastern counties the seed should be drilled as early as possible in spring. Where drilled in barley, it is often wise to drill the sainfoin immediately the barley has been sown. In a wet season there may be the disadvantage of having the sainfoin too high at harvest time, but this is a rare experience in the eastern counties. The seed

SAINFOIN (*Continued*)—

is drilled with an ordinary corn drill, and at right angles to the rows of the nurse crop. It is essential to have not only a fine tilth, but also a firm seed bed before seeding. Seed may be sown either milled or unmilled—that is, either without or with the seed coat or " cosh," as it is more generally known. The usual rate of seeding for unmilled seed is 4 bushels or 1 sack per acre, but on heavy soils it almost certainly pays to sow as much as 5 bushels. This is equivalent to a seeding of 50 to 60 lbs. per acre of milled seed.

As might be expected, unmilled seed takes longer to germinate than milled, but apart from that there is no particular advantage of one as compared with the other, except, perhaps, with regard to purity. Milled seed should be absolutely pure, but with unmilled there are usually impurities of anything up to 3 per cent., the commonest being Burnet (*Poterium Sanguisorba* and *P. muricatum*).

Manuring—Like other legumes, sainfoin is greatly benefited by applications of farmyard manure, but in practice it is uncommon and, indeed, not convenient to apply dung direct to the crop. On the other hand, the crop responds very markedly to artificial manures. It has already been pointed out that to grow sainfoin successfully the soil must be well supplied with lime, but no advantage will be secured by liming the crop after it is established. Applications of phosphate and potash are most beneficial, but on heavy soils the potash may be omitted. On light soils, phosphate as superphosphate, and potash as kainit, should be applied either before the sainfoin is drilled or as soon as possible after the nurse crop has been harvested. A less soluble form of phosphate, such as basic slag, or ground mineral phosphate, is usually more suitable for heavy soils.

If the ground is dry the young plants of sainfoin may be grazed in the autumn, but such grazing should be superficial and not intensive, for should the plants be grazed so hard that the crowns are eaten out, then the subsequent hay crop will be very greatly reduced, or may be destroyed altogether. Such grazing should be done by sheep only, and not by cattle. If the land shows any tendency to "tread" or "poach," stock should be removed immediately.

Hay—Sainfoin comes into flower fairly early, and for this reason is much appreciated by the bee-keeper. Sainfoin hay has a very high feeding value; Wood shows it to have a starch equivalent of 37 per cent., containing 10 per cent. digestible protein (" Rations for Live Stock," *Min. Agric. and Fish.*, Misc. Pub. No. 32, 1930). Sainfoin hay is in great demand for thoroughbred studs and pedigree flocks of sheep, and commands a higher price per ton than clover or clover mixture hay.

The hay is cut when the plants are just coming into full bloom, and if left until later the flower stalks become woody, the value of the hay deteriorates. The haymaking operations are directed towards preserving all the leaf, as on this the feeding value of the hay largely depends. Consequently it is customary to leave it in the swath for as short a time as possible, and then put into cocks from which it is stacked. In favourable seasons the cocks may be dispensed with, and

SAINFOIN (*Continued*)—

after once turning in the swath, it may be swept straight to the stack. Mechanical hay loaders and sweeps now make haymaking easier, and tend to the production of fodder of better quality. The average yield of hay from Giant Sainfoin is from 30 cwts. to 2 tons per acre, according to the season.

The best yields of hay are not obtained from Common Sainfoin until the third year, and where cultivations and manuring have been carried out properly, yields of 3 tons per acre and over are by no means uncommon.

Seed Production—When the hay crop of Giant Sainfoin has been removed, it is customary to save part of the aftermath for seed, the remainder being grazed usually by sheep in folds. After grazing, or after the seed crop has been harvested, the stubble is broken up and sown with winter corn. This, of course, applies only to the lighter class of soils and where the giant variety is being grown. The time of cutting a crop grown for seed has to be judged by the ripeness, which is evidenced by the change in colour and the tendency of the seed to fall off. The seeds at the bottom of the inflorescence ripen first, and as they are the best, cutting is done when they are mature. Great care is required in "making" and stacking the seed crop, so that as little as possible of the seed is lost. Thrashing is done with an ordinary thrashing machine. The straw or "stuvver" which is left is very woody and hard, but after it has been chaffed it is used largely for feeding to bullocks. The "chaff," which is really the dried leaves, forms a very valuable feed for all classes of livestock.

The yield of seed naturally varies greatly, but from 25 to 30 bushels per acre of unmilled seed is considered a satisfactory crop.

The saving of seed of Common Sainfoin is different in that a hay crop is not taken first, and that a seed crop is not taken until about the third year. The crop may be lightly grazed with sheep in early spring, and then "shut up" until the seed crop is ready—usually about the end of July. The same operations and precautions are necessary for saving seed of this variety as for the Giant Sainfoin.

Although sainfoin may not possess the same general adaptability as lucerne for the sheep farmer, it is, nevertheless, on the whole a more valuable crop. Lucerne is essentially a plant for hay. Sainfoin, on the other hand, will yield as heavy cuts of hay as lucerne, and in addition possesses, as a pasture plant, a value that cannot be approached by its rival.

(For description of diseases and insect pests see Diseases of Pasture and Forage Crops; and Insect Pests of Root and Forage Crops, under Legumes, Breeding of Herbage.)

Bibliography.—Lisle, "Observations in Husbandry"; Percival, "Agricultural Botany," Duckworth, London; Wilson, "Our Farm Crops," Blackie and Son, London; Shaw, "Forage Crops," Orange Judd Company, New York; Clark and Malte, "Fodder and Pasture Plants"; Garnier, *J.R.A.S.E.*, vol. vii., 1896; Malden, "Farm Crops," Ernest Benn, London.

J. C. L.

SALSIFY—See Market Gardening.

SALTS—A class of chemical substances formed by the union of a base and an acid, with elimination of the elements of water, thus:

$$\underset{\text{base}}{\overline{\mathrm{B}}\mathrm{OH}}+\underset{\text{acid}}{\mathrm{H}\overline{\mathrm{A}}}=\underset{\text{salt}}{\overline{\mathrm{B}}\overline{\mathrm{A}}}+\underset{\text{water}}{\mathrm{H_2O}}.$$

Acid-salts are formed when only a part of the hydrogen of the acid is replaced by the basic radicle; *e.g.*, with caustic soda as base and sulphuric acid as the acid we may have:

$$\mathrm{NaOH}+\mathrm{H_2SO_4}=\underset{\text{acid-salt}}{\mathrm{NaHSO_4}}+\underset{\text{water}}{\mathrm{H_2O}}.$$

The so-called *basic salts* are not quite analogous to the acid-salts above described; they usually contain an excess of the oxide or hydroxide of the metal or base concerned; *e.g.*, one of the basic acetates of lead has the formula $Pb_2O(CH_3COO)_2$, while basic lead arsenate is $Pb(PbOH)(AsO_4)_3H_2O$. Even the substance $(BiO)NO_3H_2O$ is sometimes called basic nitrate of bismuth, though in this case the term oxy-nitrate or subnitrate is more usual.

It must not be thought that an acid-salt is necessarily acid in its reaction to indicators, or basic salts alkaline or neutral; *e.g.*, sodium bicarbonate ($NaHCO_3$) is distinctly alkaline, while most basic salts are insoluble powders. Even so-called neutral salts corresponding to $\overline{B}\overline{A}$ (above) are not necessarily neutral; *e.g.*, copper sulphate ($CuSO_4$) is acid to litmus, while sodium acetate is alkaline. In these cases one may take it that a salt of a weak base and a strong acid is usually acid, while a salt of a strong base and a weak acid is alkaline.

The term is also used colloquially to mean the purgative medicines Epsom salts and Glauber's salts, which are the sulphates of magnesium and sodium respectively. (See also articles Acids; Soils; Metabolism, Mineral.)

SCORZONERA—See Market Gardening.

SCOTLAND—Agriculture of, see Agriculture.

SEAKALE—See Market Gardening.

SEAWEED—See Fertilizers, Miscellaneous.

SEED, Artificial Drying of—In the British Isles climatic conditions, as a general rule, operate to produce a high moisture content in all classes of seed, with additional emphasis towards this condition in seasons and in districts of heavy rainfall. In extreme cases the moisture content of cereals, for instance, may be 20 per cent. or even higher, when, if stored in large bulks, there is very considerable danger of the evolution of sufficient heat to kill the seed. Even if this stage is circumvented by repeated turning, which is a costly procedure, there still remains the liability to changes resembling those preceding true germination in the seed, which, if maintained for a sufficiently long period, impairs the vigour of germination when it is ultimately required. During the time that this incipient germination is in operation carbon dioxide is

(*Continued*)—
evolved, and this, if not removed by aeration, may exert a sufficiently toxic action on the germ to cause its death.

The extreme effect of excessive moisture in seed, *i.e.*, a rapid rise in temperature, is readily appreciated, but that produced by the longer drawn out process of incipient germination is less easily detected. It nevertheless accounts probably for greater losses in the aggregate than heated seed, which exhibits certain unmistakable physical characteristics and can consequently be readily detected.

In some parts of the British Isles subject to high rainfall, the difficulty of retaining seed in a viable condition through the winter has been perpetual. As a result it has become the recognized custom in such parts to dry the seed artificially immediately after harvest on an ordinary malt-drying kiln, or, more recently, in one of the several new types of drying machines now available for this particular and for other similar purposes. All cereal grain and many other seeds are amenable to preservation by this means.

In Ireland the high humidity of the air and the consequent difficulty of retaining barley in good " condition " has resulted in the practice of the rapid transference of the barley crop from the farmers' to the maltsters' hands, and the main portion of the crop is thus in malting stores by the end of November. To store quantities of grain of these proportions, a portion of which is utilized for seed in the following spring, but the whole of which is required to germinate, within reasonable limits of space, and in such a manner as to avoid loss by overheating, is an undertaking of considerable magnitude. It would, indeed, be almost a practical impossibility, if the only solution were the deposition of the grain in thin layers accompanied by continual turning to secure adequate aeration.

Instead, the grain is dried by hot air, either on a malt-kiln, or otherwise, until the moisture is reduced to about 12 per cent., at which figure it will retain its vitality for at least a year when stored in an ordinary granary. The moisture content of most seeds may be reduced safely to a still lower figure, but there is no advantage in carrying the reduction to a lower figure than that at which the seed may be kept in bulk without damage. In practice, as soon as possible after arrival at the maltings the grain is subjected to a temperature of about 60° F., rising to 90° F. within three or four hours of the commencement of drying. After this initial period the temperature may be still further slowly raised, but it should not exceed 120° F. at any time. In the case of wheat and oats, the maximum safe temperature is 110° F. Drying is continued for from eighteen to twenty-four hours, during which time the grain (if dried on a kiln) is turned at definite intervals to ensure thorough aeration and the removal of the vaporized moisture. The larger the amount of moisture present in the grain at the commencement of the operation, the greater is the necessity of exercising care in raising the temperature gradually and of securing the rapid escape of vaporized moisture.

Apart from the greater facility in handling the grain, it may be stored with safety to considerably greater depths after drying, and the

SEED (*Continued*)—

necessity for further turning is obviated. This, however, is not the only benefit secured, for the drying exerts a beneficial effect on the seed itself. By checking incipient germination the seed maintains a high degree of germinative energy, and repeated trials have demonstrated the greater vigour of crops from kiln-dried seed when contrasted with those from seed left through the winter, without the treatment described above. Drying also secures an even germination, and all the seeds of a crop tend consequently to commence growth and to maintain development at the same rate, a particularly desirable result in the case of malting barley, where evenness in the ultimate ripening of the grain is a most desirable feature.

Beaven has shown that the effect of slowly drying barley artificially on the quality of the grain is similar to that produced by " sweating " in the stack; the grain undergoes a certain amount of mellowing, thereby rendering it better malting material ("Varieties of Barley," *J. Instit. Brewing*, vol. viii., No. 5, 1902).

An account of the methods of kiln-drying and storing cereal seed, given in Lisle's " Observations in Husbandry," vol. i., 1757, forms an interesting and pointed commentary on the subject as it appeared to those concerned with the preservation of grain in bulk, and of seed, in the earlier part of the eighteenth century.

Wheat, oats, and many other of the smaller agricultural seeds are now dried artificially, when such treatment is necessary. In the case of small seeds which pack more closely together in bulk special precautions must be observed to secure the rapid removal of the vaporized moisture.

SEED CONTROL—In 1861 Regulations were in operation in Switzerland enabling Government Inspectors to examine seeds offered for sale in any seed shop or seed warehouse, and to deal suitably with cases of fraud. The first seed testing station, however, appears to have been established by Professor Fr. Nobbe at Tharandt, in Germany, in 1870. Shortly afterwards, Mr. E. Möller Holst started a system of control of seeds in Denmark and founded his seed testing offices. Following this, various methods of seed control were established in Holland, Germany, Hungary, the United States and several British Colonies.

The first step towards seed control taken in this country was the passing of the Adulteration of Seeds Act, in 1869. This Act makes it an offence if any person, with intent to defraud, kills or dyes seeds, or sells seeds which have been killed or dyed.

A Departmental Committee, appointed in 1900 by the then Board of Agriculture to inquire into the conditions under which agricultural seeds were being sold in this country, recommended that farmers should be advised to purchase seeds subject to a guarantee of quality by the seller, and that they should have their seeds tested. To facilitate this, the Committee suggested the establishment of a central Government seed testing station. An official seed testing station was, in fact, started in Ireland in the same year (1900), and a similar estab-

SEED (*Continued*)—

lishment was set up in Scotland early in 1914. The Irish Department of Agriculture subsequently secured some measure of control over the sale of seeds in Ireland by the passing of the Weeds and Agricultural Seeds Act of 1909, but it was not until the pressing need for stimulating the production of home-grown food arose during the War that steps were taken to introduce legislation controlling the seed supply of the country as a whole. During the earlier days of the War the necessary official control of farmers' supplies had been in the direction of (*a*) increasing and assuring output, (*b*) regulating and fixing prices, and (*c*) requiring disclosure of quality. Of these, the compulsory disclosure of essential facts as to quality gave the greatest promise of permanent value, and it was this principle which formed the basis of the first Testing of Seeds Order, made by the Food Controller in 1917, under the Defence of the Realm Regulations. The scope of this Order was slightly extended by a new Order which replaced the earlier one in July, 1918, and remained in operation until its requirements were made permanent by the passing of the Seeds Act in 1920. This Act, together with the "Seeds Regulations" made thereunder, represents the measure of control of seeds existing in this country to-day.

The main object of this Act and Regulations is to protect the farmer from unwittingly purchasing and sowing seed of poor vitality, or with a low percentage of purity. For this purpose it is obligatory on the seller, in the case of a sale of any of the principal kinds of farm and garden seeds, to deliver a statement, in writing, to the purchaser, containing certain prescribed particulars relating to their quality. A similar statement is also required to be displayed in close proximity to the seeds when exposed for the purpose of sale. The particulars which it is necessary to give in the statement referred to vary with the different kinds of seeds. It is clear that the value of a parcel of seeds to the farmer depends largely upon the percentage of purity and germination. These particulars must, therefore, be stated in connection with the sale of practically all kinds of scheduled seeds. In considering the question of purity, it is of importance that attention should be paid to the nature of the impurity. If the impurities consist of such things as other useful seeds, broken seeds, and inert matter, no serious harm is done. If, however, they consist largely of weed seeds, serious loss may result to the farmer, not only by the fouling of his land, but by the loss of plant food to the crop he is growing. Impure seeds do most harm when introduced in mixtures of grasses and clovers, the product of which may occupy the ground for several years. For this reason, in the case of a sale of grass or clover seed, the Seeds Act requires the seller to state, in addition to the percentage of purity, the total percentage, by weight, of certain specified injurious weed seeds. The Act also makes it illegal to sell, or knowingly to sow, any seeds, to which the Act applies, if they contain more than 5 per cent. of injurious weed seeds. The injurious weed seeds scheduled under the Act are those of Docks and Sorrel (*Rumex* spp.); Cranesbills (*Geranium* spp.); Wild Carrot (*Daucus Carota*, L.); Yorkshire Fog (*Holcus lanatus*, L.); and Soft Brome Grass (*Bromus mollis*, L. et spp.).

SEED (*Continued*)—

There are, of course, many other kinds of weed seeds the presence of which is most undesirable, but the above have been selected as being the most noxious and consequently the most necessary to be disclosed. The Regulations also require disclosure of the presence of the seeds of dodder, a parasitic plant capable of causing serious damage to clover crops, particularly when grown in the south of England.

Other items which must be shown in the statement made in accordance with the requirements of the Seeds Act include (*a*) the country of origin in the case of grass and clover seed; (*b*) the Imperial bushel weight in the case of rye grass seed; (*c*) when burnet is present in sainfoin; (*d*) the percentage of suckling clover when it is present in certain kinds of cultivated clovers; and (*e*) in the case of clovers, trefoil, lucerne and sainfoin, the percentage by number of "hard seeds," as distinct from the percentage number of the seeds that germinate during a germination test.

In addition to the particulars above, the statement must include the name and address of the seller; a declaration that the seeds have been tested in accordance with the requirements of the Act; in all cases, the kind of seed sold or exposed for sale; and, in certain cases, the distinctive name of the variety.

Concurrently with the passing of the first Testing of Seeds Order, an official seed testing station was established at Cambridge by the Ministry of Agriculture and Fisheries. The duties of this station are (1) to test samples of seeds submitted by seed merchants and others who require particulars as to the germination, purity, etc., of the seed for the purpose of the declaration which they are required under the Seeds Act to make in the case of a sale, or of exposure of seed for sale; (2) to test samples of seeds submitted by farmers who wish to ascertain whether bulks of home-grown seed are fit for sowing, or to check the particulars supplied with purchased seed, and (3) to test samples of seed taken for control purposes by Inspectors of the Ministry of Agriculture and Fisheries, in connection with the administration of the Seeds Act. The Scottish Official Station is at East Craigs, Corstorphine, and the Station of the Ministry of Agriculture for Northern Ireland at Belfast.

The sale of seed potatoes in this country is also governed by regulations which require, in the case of a sale or exposure for sale of potatoes intended for planting, a statement to be given by the seller including particulars as to (*a*) the variety, (*b*) where the seed was produced, and (*c*) the size. It is also necessary, in connection with the control of potato disease, that every lot of seed potatoes sold shall be the subject of a certificate issued by the Ministry of Agriculture and Fisheries, and that the reference number of this certificate shall be quoted at the time of sale.

Under the Corn Production Acts (Repeal) Act, 1921, the Minister of Agriculture and Fisheries is empowered to serve a notice upon the occupier of any land where certain injurious weeds are known to be growing, requiring the occupier to cut down or destroy the weeds in the manner, and within the time specified, in the notice. If the

SEED (*Continued*)—

occupier unreasonably fails to comply, he is, on summary conviction, liable in respect of each offence to a fine not exceeding £20, and to a further fine not exceeding 20s. for every day during which the default continues after conviction. The Minister's powers in this connection were delegated to agricultural committees by the Agricultural Committees (Injurious Weeds) Order, 1921, but the Minister's consent must be obtained, in each case, before legal proceedings under the Act are instituted. The injurious weeds in respect of which action may be taken are spear thistle, creeping or field thistle, curled dock, broad-leaved dock and ragwort. Similar powers are exercised in Scotland, under the same Act, by the Department of Agriculture for Scotland; and under the Weeds and Agricultural Seeds (Ireland) Act, 1909, in Northern Ireland by the Ministry of Agriculture, and in the Irish Free State by the Department of Agriculture. In the case of Ireland the specified noxious weeds are ragwort, charlock, coltsfoot, thistle, and dock.

A. T. A. D.

SEED, CHEMICAL TREATMENT OF—Chemical disinfection of seed before sowing ("seed pickling") is the means adopted for preventing certain fungus diseases which are carried on the seeds of the host plant. Of these, the most important are diseases of cereal crops known as Bunt or Stinking Smut of wheat caused by *Tilletia caries* and *T. fœtens*, the "Covered Smut" of barley (*Ustilago hordei*) and the Covered and Loose Smuts of oats (*U. kolleri* and *U. avenæ*). Leaf Spot of celery (*Septoria apii*) is another seed-borne disease which can be prevented by chemical treatment of the seed. Loose Smuts of wheat and barley (*U. tritici* and *U. nuda*) cannot, however, adequately be dealt with in this manner, since in these species the fungus is present, not on the surface, but within infected seeds. (See Seed, Transmission of Diseases by.)

Wet Treatments—Steeping the seed in salt solution was advocated as a partial remedy for smutted corn from a very early date. Towards the end of the eighteenth century treatment of the seed for some hours with a solution of copper sulphate was suggested, and this method has been carefully studied and widely adopted. The older plan was to immerse the sacks of corn completely in the liquid, but this was a troublesome process, involving prolonged drying of the seed; it has been abandoned in favour of sprinkling the solution on to the heaps of seed, which are carefully turned so that every grain is wetted, and then dried as rapidly as possible in a thin layer. Treatment with milk of lime, or powdered lime, immediately after the copper sulphate solution has sometimes been recommended, particularly in the case of seed barley. The strength of the solution of copper sulphate employed should be 2·5 per cent. (2½ lbs. per 10 gallons of water), though 10 per cent. solutions have often been used. Treatment with copper sulphate is on the whole an efficient method, but the results are somewhat uncertain and there is danger of injury to the seed, involving loss of germinating power, particularly if strong solutions

SEED (*Continued*)—

are used. The amount of injury appears to depend largely on the extent of the mechanical damage which has been inflicted on the grain during the processes of harvesting and thrashing; seed with a perfectly undamaged seed coat does not appear to be injured by copper sulphate (Brown, *Ann. Bot.*, xxi., 79, 1907).

In recent years, copper sulphate has been largely superseded by formaldehyde for seed pickling. Formaldehyde is a very powerful antiseptic, generally sold as a 40 per cent. solution under the name *Formalin.* Salmon and Wormald (*J. Min. Agric.*, xxvii., 1013, 1921; xxix., 722, 1922) carefully compared formalin and copper sulphate for preventing Bunt in wheat, and came to the conclusion that the former was more efficient and, used at about 0·3 per cent. (1 pint of formalin to 40 gallons of water), was less liable to cause injury to the seed. The solution, at the rate of about 1 gallon per 2 bushels, is sprinkled over the seed with constant turning, so that every grain becomes wetted, after which the grain is heaped together, covered with sacks moistened with the formalin solution, and left for four hours. Finally, it is spread to dry in a thin layer on a clean floor, care being taken to avoid re-infection. It is important to dry the grain and sow it as soon as possible after treatment, as injury may occur on storage (see Hurd, *J. Agric. Res.*, xx., 209, 1920). The formalin treatment is also effective for the prevention of Covered Smut of barley and of Covered and Loose Smuts of oats. A preliminary soaking of the seed with water before treatment with formaldehyde or copper sulphate has been recommended as a means of reducing any risk of loss of germinating power (Braun, *J. Agric. Res.*, xix., 363, 1920; *Phytopath.*, xii., 173, 1922). If the formalin process is carried out carefully, however, such risk is very small (see *Min. Agric. and Fish.*, Leaflets Nos. 92 and 328).

A dilute solution of formaldehyde has sometimes been employed for the disinfection of "seed" potatoes to prevent Scab and other fungus diseases. Preparations containing mercuric chloride (corrosive sublimate) have also been proposed for treatment of "seed" potatoes and cereals against certain fungus diseases and have proved efficient, but this substance is so excessively poisonous to human beings that its use for a purpose of this kind must necessarily be very limited.

More recently, a number of organic mercury compounds, which are less poisonous to man than mercuric chloride, have been found to possess powerful fungicidal properties, and a number of preparations of these substances are on the market as seed disinfectants. Most of these are proprietary products, of which "Uspulun," "Semesan," "Ceresan," and "Germisan" may be mentioned as examples. The active ingredient in many cases is the sodium salt of a mercury compound of a phenol or cresol derivative. The use of these preparations for the control of various seed-borne diseases has met with considerable success, and the solutions or powders appear to have no injurious effect on the seed. A stimulation of growth has, in fact, been claimed.

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Dry Treatments—Within the last ten years the employment of commercial *copper carbonate* (chemically a basic copper carbonate) in the form of a fine dusting powder has been very widely adopted for seed disinfection, especially in Australia, where the method was first suggested, and in the United States. The advantages of a dust for seed treatment in avoiding the making up of solutions and the subsequent drying of the grain are evident, and the chief difficulty of application lies in ensuring that mixing should be thorough enough to get every grain coated with the powder. Good results have been obtained with copper carbonate against Bunt of wheat, using about 2 ozs. per bushel, and no injury to the seed has been noted (Sampson and Davies, *Welsh J. Agric.*, ii., 188, 1926 ; Woodward, *N. F. U. Year Book*, 1927). Other dusts containing copper compounds have been tested, but none has proved more efficient than copper carbonate. The method has not so far proved so effective against the Smuts of barley and oats.

Some of the organic mercury compounds already referred to are sold for use as dusts and certain preparations containing organic arsenic compounds have also found a use as dry seed fungicides. "Tillantin," a German proprietary product, is an example of the latter.

C. T. G.

SEED, PHYSIOLOGICAL PRE-DETERMINATION OF—Pronounced effects upon the growth and final yield of the plant can often be traced back to the environmental conditions obtaining during germination and dormancy, and in the seedling stage, or even earlier whilst the seed is still attached to the parent plant. Such effects have been termed effects of physiological pre-determination in order to distinguish them from those due to hereditary causes. Under the general title "Physiological Pre-determination," the literature dealing with the influence upon the resulting plant of a variety of factors which affect the seed, before and during germination, has been critically reviewed in a series of articles, the last of which appeared in 1919 (F. Kidd and C. West, "Physiological Pre-determination: The Influence of the Physiological Condition of the Seed upon the Course of Subsequent Growth and upon the Yield," Review of Literature, chapters i.-iv., *Ann. App. Biol.*, v., pp. 112-141, 157-170, and 220-251, 1918; vi., pp. 1-26, 1919). For a detailed account of the earlier work on this subject, including a comprehensive bibliography, the reader is referred to this review. The following is a brief résumé of the earlier work and of some of the more important work which has appeared since the publication of the review of the literature.

The factors which determine the "potentiality" of the seed, by which is meant the capacity of the resulting plant for growth and yield, may be classified under the following categories:

A. Parental conditions.
B. Harvesting conditions.
C. Conditions during, or immediately preceding, germination, or in the very early stages of seedling growth.

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A. Parental Conditions—The problem of the pre-determining effect of parental conditions is complicated by the ever-present possibility of hereditary factors being concerned, and in most of the experimental work on this subject the facts have been considered mainly from the point of view of heredity. There are to be found in the literature, however, a number of observations which strongly indicate that the climatic, edaphic, and other agronomic factors, which constitute the environment of the parent plant, and also the position of the seed upon the parent plant, play an important part in determining the potentiality of the seed. The effect of parental conditions has been clearly demonstrated by the investigations of J. F. Hofmann ("Adaptation in Douglas Fir," *Ecology*, ii., p. 127, 1921). In the autumn of 1912 Hofmann gathered seed from 127 Douglas fir trees representing twenty-nine different conditions, each of which involved the influence upon the parent tree of one or more of the factors, soil, age, elevation, locality, size, etc. Data were presented which constitute the summarized results of six years' work, including six annual germination tests and the growing of one-year-old stock from each germination series. Each parent tree was represented by a test of 300 seeds in each series. The results of this study proved that the influence of the environmental conditions of the parent tree is reflected in its progeny. To take one example, a direct comparison was made of the age classes of trees grown under exactly similar conditions. The youngest trees produced the largest (average) cones, and the largest cones contained the largest seeds. It was shown that the age of the parent tree affected the vitality of the seed, loss in vitality increasing with the age of the parent tree, and that this loss of vitality was reflected in the vigour of the seedlings and resulting plants.

The question as to whether the potentiality of the seed is influenced by its position on the parent plant has been investigated by Y. Yamaguchi ("Kurze Mitteilung über die Bezeihung der Aufblühzeit und das Sitzes der Blüte am Rispenaste zum Korngewichte des Reises," *Bot. Mag. Tokyo*, xxxiv., p. 136, 1920), who showed that a correlation exists between the weight of rice seeds and their position on the panicle.

Effect of Size and Weight of Seed—Differences in the size and weight of the seed due either to the position of the seed on the parent plant or to the parental environment are often noticeable, and several critical comparative studies have been made, both under field conditions and in the laboratory, of the germination of such seeds and of the development and yield of the resulting plants.

When estimating the effect of size of seed upon growth and yield, so many factors in addition to the hereditary factor must be taken into consideration that it is not surprising that many contradictory results have been obtained. Moreover, the methods employed by the numerous investigators have differed widely; consequently many of the results are not comparable.

The importance of the hereditary factor has been emphasized by W. M. Findlay ("The Size of Seed," *North of Scotland Coll. of Agric.*

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Bull., xxiii., 1919), by E. S. Beaven (" Breeding Cereals for Increased Production," *J. Farmers' Club*, November, 1920), by N. A. Rotunno (" Effect of Size of Seed on Plant Production, with Special Reference to Radish," *Bot. Gaz.*, lxxvii., p. 397, 1924), and by R. G. Stapledon, W. Davies, and A. R. Beddows (" Seeds Mixture Problems: Soil Germination, Seedling and Plant Establishment with Particular Reference to the Effects of Environmental and Agronomic Factors," *Welsh Plant Breeding Station, Publication No.* 6, 1927). For example, it has been shown by Findlay that in a genuine sample of seed of oats, turnips, and red clover, the large seeds produced a larger crop than the small seeds, whereas in different samples of the same kind of seed the strain and origin were of more importance than the size of the seed. Beaven, whilst emphasizing the importance of inherited tillering capacity in cereals, points out that in the case of barley the largest nitrogenous seeds produce the plants which tiller best, equal soil space per plant being given.

The effect of the crop husbandry in the case of cereals has been traced upon seeds of different size grades, their germination, early growth, and yield, by T. A. Kiesselbach (" Relation of Seed Size to Yield of Small Grain Crops," *J. Amer. Soc. Agron.*, xvi., p. 670, 1924), and by M. G. Jones and M. A. H. Tincker (" Yield Studies in Oats: The Effect of the Pre-Treatment of the Parent Crop upon the Seed Produced, its Germination and Subsequent Growth," *Ann. Appl. Biol.*, xiii., p. 535, 1926). In 1924, Kiesselbach summarized all the available published field data dealing with grain yields from seed grades of small grain crops as follows:

" (1) When the space planting was such as to permit maximum development, the individual plant grain yield was 19 per cent. less for the small than for the large seed. This difference is due to the immediate advantage of a greater reserve food supply in the larger seed which results in a more vigorous initial growth.

" (2) When planted in equal numbers at a rate optimum for the large seed, the small seed yielded 11 per cent. less grain per acre than the large.

" (3) When planted in equal weights at a rate optimum for the large seed, the small seed yielded 3 per cent. less, and the unselected seed yielded 2 per cent. more per acre than the large seed. The relatively low yield of plants from small seed was largely overcome by planting a greater number of seeds."

He concluded that in general there appeared to be no material or practical gain in the grain yield, under farm conditions, from the practice of grading small grain seed which is reasonably free from trash.

The growth response to seed size of a biennial plant (*Brassica oleracea capitata*) under field conditions was investigated by F. Kotowski (" Effect of Size of Seed on Plant Production," *Acta Soc. Bot. Poloniæ*, iii., p. 253, 1925; also *Proc. Internat. Congress Plant Sci.*, ii., p. 974, 1929). During the first sixty days the size of seed had a definite influence on the size of the seedling plant, but in the later stages of

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development this effect tended to disappear. The actual productiveness of the plants was not dependent upon the size of the seed sown, for the small seeds produced plants giving yields at least as high as those from the large seeds. Moreover, a larger percentage of marketable heads was produced from the small seeds.

Comparing the potentiality of rape seeds of different size grades, M. J. Sirks (" Farbe und Grösse der Samen von Raps in ihrer physiologischen und züchterischen Bedeutung," *Med. van. de Landbouw. te Wageningen*, xxx., p. 3, 1926) observed that the plants which developed from the larger seeds were taller and came into flower earlier than those from the smaller ones.

From a consideration of the available published evidence it would appear that the conclusion is justified that *in general under field conditions larger seeds give rise to more vigorous plants, especially in the seedling stage, and that in certain cases a better yield can be obtained by the use of large seed.*

Confirmation of the above generalizations is provided by the results of laboratory experiments, in which the comparisons have been made under carefully controlled conditions, the plants being grown either in soil cultures or in culture solutions. D. Schmidt (" The Relation of Seed Weight to the Growth of Buckwheat in Culture Solution," *Soil Sci.*, xv., p. 285, 1923) grew buckwheat plants from seeds of five different weight grades, in culture solutions, under experimental conditions which were strictly comparable for all the plants, and periodically made several quantitative measurements, such as dry weights, leaf areas, etc. It was found that, except in the case of abnormally heavy seeds, the order of superiority of the plants grown from the heavier seeds over those grown from seeds of lighter weight corresponded to the order of seed weight, and the superiority of the plants produced from heavier seeds over those produced from lighter seeds was maintained from the early seedling phase to maturity. The same author (" The Effect of the Weight of the Seed on the Growth of the Plant," *New Jersey Agric. Expt. Stat. Bull.*, 404, 1924) grew soy beans, buckwheat, lima beans, and corn from seeds of different weights, in soil cultures under experimental conditions, and obtained results which differed from the above only in the fact that the superiority of the plants produced from the heavier seeds decreased appreciably as the plants approached maturity, in certain cases disappearing entirely.

Results of a somewhat similar nature are recorded by W. Rudolfs (" Influence of Temperature and Initial Weight of Seeds upon the Growth Rate of *Phaseolus vulgaris* Seedlings," *J. Agric. Res.*, xxvi., p. 537, 1923). Bean seeds of different size grades were grown in greenhouse soil with 60 per cent. of its water-holding capacity at constant temperatures of 5°, 10°, 15°, and 20° C. Under these uniform conditions the plants which developed from the heavier seeds showed a distinct advantage over those produced from seeds with a lighter initial weight. The larger seeds had a normal temperature coefficient, whereas in the case of the smaller seeds the temperature coefficient was found to be abnormally small. From this it was inferred that

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the amount of food reserves in the seeds is of major importance for early growth.

Using the water-culture method, W. E. Brenchley ("Effect of Weight of Seed upon the Resulting Crop," *Ann. Appl. Biol.*, x., p. 223, 1923) found in the case of peas and barley a steady rise in the dry weight of the plants as the initial weight of the seed increased. This occurred both with a limited and with an abundant food supply. The interesting fact was established that the rate per cent. increase per day falls gradually as the weight of the seed rises, so that with prolonged periods of growth there is a tendency for the initial advantage gained by plants from the heavier seeds to disappear.

Brenchley's conclusions are supported by S. F. Trelease and H. M. Trelease ("Relation of Seed Weight to Growth and Variability of Wheat in Water Cultures," *Bot. Gaz.*, lxxvii., p. 199, 1924), who showed that the dry weight of wheat plants grown in culture solutions was directly related to the original seed weight, the highest yields being obtained from seeds of heavy weight.

B. Harvesting Conditions—The degree of maturity of the seed at the time of harvesting is affected not only by the parental environment, but also by earlier harvesting. In either case it is not easy to compare the potentiality of immature seeds with that of mature seeds owing to the complication of a certain period of storage in the case of the former. It is a well-established fact that immature seeds are less tolerant of storage in the dry condition than mature seed, so that in the case of most of the comparative trials which have been carried out, the total yields from the immature seeds have been smaller than those from fully ripe seeds owing to the fact that a smaller percentage of the immature seeds has germinated.

When in such experiments comparisons are made between yield per plant, however, the difference in favour of the plants from mature seeds tends to disappear, or even to be reversed. This result may be significant, but it must be remembered that while the yield per plant in the case of the mature seeds represents an average based on a whole population (*i.e.*, both vigorous and weak plants), the yield per plant in the case of the immature seeds, on the other hand, probably represents an average based on the more vigorous members of the population only, the others having perished during storage in the seed stage.

From the point of view of the grower, seed harvested at a stage somewhat previous to maturity may, under certain conditions, give a better yield than seed allowed to become dead ripe upon the parent plant; but it must be borne in mind that immature seed does not withstand storage as well as seed which has been allowed to become fully ripe, so that—as a general practice—*the use of immature seed is not to be recommended.*

Amongst the more recent papers dealing with this aspect of physiological pre-determination, the following may be mentioned: M. G. Jones, "Preliminary Investigations with Oats," *Welsh Plant Breeding Station Bull.*, Series C, No. 3, p. 19, 1923; M. Kondo ," Ueber Nachreife

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und Keimung verschieden reifer Reiskörner (*Oryza sativa*, L.)," *Ber. des Ōhara Inst. für landw. Forsch.*, i., p. 361, 1918; also "Beiträge zur Kenntnis der Keimungsphysiologie des Reissaatkörner (*Oryza sativa*), des Wachstums ihrer Keimpflanzen und des Beschaffenheit des Reissaatbeetes," *Ber. des Ōhara Inst. für landw. Forsch.*, ii., p. 291, 1923; Y. Yoshii, "Ueber die Reifungsvorgänge des Pharbitis-Samens mit besonderer Rücksicht auf die Keimungsfähigkeit des unreifen Samens," *J. Faculty Sci. Imp. Univ. Tokyo*, i., p. 1, 1925.

C. Conditions during, or immediately preceding, Germination, or at the very Early Stages of Seedling Growth—The external conditions operating upon the seed during the critical stages of germination play an important part in determining the vigour of growth and the yield of the resulting plant. Various methods have been employed in endeavours to stimulate and accelerate seed germination, but in few cases have the effects upon subsequent growth and final yield been studied. The experiments in which this has been done, although few in number, are of considerable interest because they point to methods by means of which an action induced during germination may favourably or otherwise affect the whole course of development.

In many cases treatments of the seed previous to or during germination have been devised primarily with a view to seed sterilization and fungus control, or with a view to increasing the percentage of seeds able to germinate. (See Seed, Artificial Drying of.) It has thus happened that observations on the physiological behaviour of the plants produced from these treated seeds have in most cases been incidental. This is unfortunate because in many cases an increase in the vigour and size of the seedlings has been noted, and because there is considerable evidence to show that a very close correlation exists between the size and vigour of the seedling, even in its earliest stages, and the final yield of the adult plant.

In dealing with the effects of specific seed treatments it is convenient to distinguish between those which directly affect the nutrition of the embryo and seedling and those which have only an indirect influence upon nutrition.

Treatments of the Seed which directly affect the Nutrition of the Seedling. 1. *Removal or Partial Removal of the Cotyledons, Endosperm, etc.*—An obvious method of varying the amount of reserve food material available for the developing embryo has been to remove, or partially remove, the cotyledons of exalbuminous seeds or the endosperm of albuminous seeds. In this way series of plants deprived of various proportions of their initial food reserves have been compared with plants from untreated seeds.

Experiments conducted on these lines are worthy of considerable attention, for although the treated seeds may not give results showing increased yields, yet they clearly demonstrate the possibility for pre-determination which exists during germination and in the early stages in the development of the seedling. In the case of certain

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annuals the effects of the amount of nutrient material originally available for the embryo are found to last throughout the life of the plant, and to be clearly visible during the stages of vegetative development, of flowering, and of seeding.

This aspect of the problem of physiological pre-determination is perhaps the most interesting because it has been studied in a more scientific manner than any other, and in certain instances dry-weight and leaf-area measurements have been made (M. C. Vyvyan, " Studies of the Rate of Growth of Leaves by a Photographic Method. I. The Determinants of the Rate of Growth of First Leaves of *Phaseolus vulgaris*," *Ann. Bot.*, xxxviii., p. 59, 1924).

The data provided by the more recent workers in this field for the most part confirm the results obtained by the earlier investigators, and fall into line with those obtained from experiments with intact seeds varying in size or weight. In other words, the following facts appear to have been established:

In the first place seedlings produced from intact seeds produce the most vigorous seedlings, and this initial advantage, at least in the case of annual plants, may persist until maturity (E. B. Brown, " Effects of Mutilating the Seeds on the Growth and Productiveness of Corn," *U.S. Dept. Agric. Bull.*, 1011, 1922).

Secondly, the reduction in rate of growth, especially during the later stages of development, is not proportional to the degree of mutilation of the seed. For example, W. R. Robbins, working in the Department of Plant Physiology of the New Jersey Agricultural Experiment Station, ascertained the effect of reducing the initial weight of oat seeds by removing portions of the endosperm as compared with uninjured seeds of the same weight. Nine different weights, each differing from the next by 15 per cent. and distributed over the range of the population, were selected. The plants were grown in soil cultures in large glazed earthenware pots. It was found that the plants produced from the mutilated seeds were retarded in the early stages of growth, but this early disadvantage was completely wiped out during the complete growth period, and at maturity all the cultures showed approximately the same dry weight.

Finally, it appears that different plants respond differently to mutilation of the seeds, for whereas no apparent difference was observed by E. S. Clark in soy-bean plants from seeds of equal weights, whether normal or mutilated, and no significance could be ascribed to a stimulative or harmful effect of injury as such, A. Urbain (" Influence des Matières de Réserve de l'Albumen de la Graine sur le Développement de l'Embryon," *Rev. Gén. de Bot.*, xxxii., pp. 123 and 165, 1920), on the other hand, found abnormal morphological and histological features in plants belonging to a wide range of natural orders grown from seeds from which portions of the food reserves had been removed. From a consideration of Urbain's results one is tempted to postulate the hypothesis that certain substances, essential for the normal growth of the plant and possibly resembling a vitamin in nature, are present in the seed reserves of certain plants. Support

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is lent to this hypothesis by the failure to develop into normal plants of embryos entirely deprived of their seed reserves, even when grown on a substrate containing all the nutrient materials generally recognized as being indispensable to plant growth (D. I. Andronescu, "Germination and Further Development of the Embryo of *Zea Mays* separated from the Endosperm," *Amer. J. Bot.*, vi., p. 443, 1919).

At this point reference should be made to the much-debated question as to whether normal germination of orchid seeds, which consist of an undifferentiated embryo without endosperm or cotyledon, is dependent upon infection of the embryo by the appropriate fungus. It is held by one group of workers, for example, H. Burgeff ("Die Wurzelpilze der Orchideen, ihre Kultur und ihr Leben in der Pflanze," Jena, 1909), that symbiosis is obligative for the normal development of orchid seeds, most of which cannot germinate when merely supplied with water and nutrient salts. On the other hand, L. Knudson ("Physiological Study of the Symbiotic Germination of Orchid Seeds," *Bot. Gaz.*, lxxix., p. 345, 1925) presents evidence that the fungus is not essential for germination, at least for seeds of *Cattleya*. Knudson germinated *Cattleya* seeds without the fungus, but with sugar, and suggests that under natural conditions orchid embryos are dependent for continued development on an appropriate supply of organic food, which is absorbed from the material on which the seeds are germinating.

2. *Soaking Seeds in Water*—The pre-determining effects of soaking seeds in water are often pronounced. From the point of view of growth and yield, it appears from the evidence that these effects may be good or bad, the result depending upon the external conditions during the soaking treatment and upon its duration. How far this form of treatment is properly included here under the head of treatments affecting nutrition is debatable. There is certainly a considerable exosmosis of soluble food reserves from seeds soaked in water, and on the basis of such results as are described above, this should cause a depression in growth and yield. On the other hand, owing to the fact that actual growth is inhibited in the embryo under water, time is allowed for a complete mobilization of food reserves in readiness for very active growth as soon as the seed is sown, so that the early stages of development may be unusually vigorous.

In the late seventies and early eighties of last century a group of German workers, notably C. Kraus and E. Wollny, investigated very fully the effect upon subsequent growth and yield of soaking seeds in water, and obtained remarkable results. These authors emphasized the importance of the conditions under which the soaking was carried out, especially with regard to the relative amount of water employed. Beneficial effects upon growth and yield were obtained when the soaking of the seed was carried out with the least possible amount of water, and they believed that the main effect of using as small an amount of water as possible lay in reducing the loss by exosmosis of essential food reserves during the process of soaking. It may be pointed out that the minimum amount of water is, at the

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same time, a favourable condition for the supply of oxygen to the seed, and for the removal of carbon dioxide from the seed during soaking. The time of immersion employed varied from twenty-four to a hundred hours according to the species of seed under investigation. Generally speaking, the time of immersion allowed was just long enough for the swelling of the seed to become complete. These authors, in view of the possible economic application of this seed treatment, carefully tested how far the re-drying of the seed would affect the results, and found that in general the re-drying of the seed after soaking, especially if carried out slowly, did not appreciably alter the beneficial influence of the process. The following general conclusions can be drawn from their experiments.

(a) *In general, seeds soaked in water previous to germination give rise to slightly fewer plants than untreated seeds. If the seeds are re-dried too rapidly the number of plants produced may be considerably diminished.*

(b) *Plants from seeds swollen in water previous to sowing develop at first more quickly than those from untreated seeds, but this initial difference in growth tends to disappear later on.*

(c) *The experimental plants have a longer growth-period and flowering period than the control plants, arrive at maturity at a later date, and give larger final yields, and this probably accounts for the fact that plants from seeds which are soaked in water previous to sowing are more productive than plants from untreated seeds.*

(d) *Soaking the seed in a relatively large volume of water, for instance, ten volumes of water to one volume of seed, reduces the beneficial effect, and may even be harmful.*

Very little has been added to our knowledge of this subject by the more recent work, the only additional point being that the temperature of the water in which seeds are soaked greatly influences the result.

3. *Seed Impregnation with Nutrient Substances*—Under the above category fall seed treatments with salts, acids, and other chemical reagents, many of which are necessarily bound up with soaking in water. This complication often renders it difficult to assess the actual value of the reagents used, and it is difficult to generalize regarding the results obtained, some of which show a distinctly beneficial effect upon plant growth as a result of the treatment of the seed, whilst others show no effect or even a harmful one. All the available evidence however, supports the conclusion that *where germination and early seedling growth are stimulated by chemical treatments of the seed, the subsequent growth and final yield are often favourably influenced in proportion.* Full details of experiments dealing with the pre-determining effects of a variety of chemical substances can be found in the following papers: W. Gleisberg ("Saatgutstimulierung, ein neuer Weg zu höheren Erträgen," *Deut. Obst. u. Gemüsebau Ztg.*, lxx., p. 28, 1924); D. Silbert ("Notes on the Stimulating Influence of Seed Treatment upon the Subsequent Growth of Plants," *New Jersey Agric. Expt. Stat. Ann. Rpt.*, p. 259, 1923); G. Friesen ("Der Einfluss der Samenvorhandlung auf Wachstums—und Reizvorgänge im Keimling,"

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Jahrb. für Wiss. Bot., lxv., p. 28, 1925; "Neue Untersuchungen über Samenvorbehandlung und ihre Folgen für die Keimpflanzen," *Ber. d. Deutsch. Bot. Gesellschaft*, xlvii., p. 69, 1929); S. M. Malinovski ("Stimulation of Hemp Seed, *Cannabis sativa*," *Mém. Inst. Agron. à Leningrade*, iv., p. 289, 1927); D. C. Smith and E. N. Bressman ("Some Effects of Seed Treatment on the Germination and Subsequent Growth of Wheat," *J. Agric. Res.*, xl., p. 25, 1930).

Other Seed Treatments. 1. *Temperature*—Many authors have dealt with the effect upon germination of storing seeds, either in the dry or in the moist condition, at high and low temperatures, but most of this work has been undertaken with the object of discovering a simple method for sterilizing seed without impairing its capacity to germinate. And even in those cases where increased growth and yield have been obtained by the use of treated seeds no distinction has been made between the actual pre-determining effects of the seed treatment upon the plant and the effects of removing fungal spores, etc. Results obtained by Wollny in 1876 and 1877, however, indicate quite definitely that in the case of a number of cereals and other economic crops dry heating the seed generally increased the productivity of the plants produced.

The embryos of many plants—for example, *Juniperus* sp., *Acer* sp., *Cornus* sp., and several genera of the natural order Rosaceæ—exhibit a definite period of dormancy during which they pass through certain important chemical changes, termed after-ripening, before they can develop into seedlings. In the case of many seeds with dormant embryos, storage at a low temperature for a certain period is necessary to enable germination to take place. The horticultural practice of "stratification" of seeds is essentially a method of storing seeds at a chilling temperature (D. A. Pack, "After-ripening and Germination of Juniperus Seeds," *Bot. Gaz.*, lxxi., p. 32, 1921; G. T. Harrington and B. C. Hite, "After-ripening and Germination of Apple Seeds," *J. Agric. Res.*, xxiii., p. 153, 1923).

In addition to its effect upon germination, low temperature treatment of seeds may exercise a remarkable pre-determining effect upon the subsequent development of the plants produced. R. Aderhold ("Ueber das Schieszen des Kohlrabis," *Mitt. Kais. Biol. Anstalt für Land.- und Forstwirtschaft*, ii., p. 16, 1906) and E. Gutzeit ("Versuche über das Schossen der Rüben und anderer Pflanzen," *Mitt. Kais. Biol. Anstalt. für Land.- und Forstwirtschaft*, vi., p. 20, 1908) showed that by exposing seeds of kohl rabi and beet, plants which normally flower in their second year, to low temperatures for short periods, the plants were induced to flower or "bolt" during the first year instead of forming storage organs. The researches of G. Gassner ("Beiträge zur physiologischen Charakteristik sommer und Winter-annueller Gewächse, inbesondere der Getreide-pflanzen," *Zeitschr. für Bot.*, x., 1918, p. 917) on the development of cereal crops in relation to climatic conditions provide us with another good example of the pre-determining effect of temperature. Gassner's experiments showed

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that by exposing the seeds of certain "winter" varieties of cereals to low temperatures during germination or during the early stages of seedling growth, flowering stems were produced and grain set during the first year. The lower the temperature used and the earlier in the plant's development the low temperature treatment was applied, the shorter the subsequent interval between germination and culm-formation. In parallel experiments carried out with "summer" varieties the time at which culm formation occurred was apparently not affected by exposure of the seeds or seedlings to low temperatures.

Further light has been thrown on these phenomena by the recent work of Maximov and others, the results of which have been brought together by N. A. Maximov ("Experimentelle Änderungen der Länge der Vegetationsperiode bei den Pflanzen," *Biol. Centralbl.*, xlix., p. 513, 1929). This pre-determining effect of low temperature has been shown to apply to quite a number of plants, and in the case of *Avena byzantina* and of *Vicia villosa* the interval between germination and flower formation was more than halved when germination took place at zero Centigrade, as compared with plants from seeds germinated at higher temperatures. Further, it has been established that at maturity the reproductive parts of the plants produced from seeds germinated at low temperatures show a marked preponderance over the vegetative ones. This is brought out by the following table, in which are presented the dry-weight data for the various organs of plants of *Avena byzantina* produced from seeds germinated at various temperatures:

Germination Temperature (C.).	*Weight as Percentage of Total Weight.*					
	Leaves.	*Roots.*	*Stems.*	*Ears.*	*Vegetative Parts.*	*Reproductive Organs.*
0°	5·8	13·2	48·2	32·4	19·2	80·8
6·5°	9·9	16·4	52·1	21·6	26·3	73·7
18°	23·8	36·1	35·4	4·7	59·9	40·1
26·5°	29·1	38·0	32·9	—	61·1	32·9

The total leaf-areas of the plants when harvested were 42, 360, 613, and 874 sq. cm. for the plants germinated at 0°, 6·5°, 18°, and 26·5° C., respectively.

It should be noted here that experiments carried out by A. M. Hurd-Karrer ("The Formative Effect of Day Length on Wheat Seedlings," *J. Maryland Acad. Sci.*, i., p. 115, 1930) have demonstrated the importance of a "short" day for the initiation of the "rosette" growth habit in autumn-sown winter-wheat plants, and have given evidence of the interrelationship of this factor with temperature and some soil condition, apparently moisture supply. The author states that this resting period, if not essential, is at least conducive to the subsequent normal growth and maturation of the plants.

SEED (*Continued*)—

2. *Electrical Treatments*—The growth results obtained from seeds which had been subjected to electrical discharge are reported by Höstermann in the *Landwirthschaftliche Jahrbücher* for 1913. Under certain conditions, especially when the seeds formed the negative electrode, an increase in growth and final yield was obtained.

C. W.

SEED, SPACING OF—An acre of corn drilled in rows 8 ins. apart will contain 7,920 ft. of drill-row in an acre, and the total yield from the acre will be the sum of the yields from the 7,920 foot-rows. Recent enquiry has shown that the production varies extremely widely from one foot to another, and that this is caused primarily by the variations in plant population. Attention has been directed to this aspect of crop production by Engledow and his co-workers (*J. Agric. Sci.*, xiii., *et seq.*), who have been led into extensive investigations of the environmental factors affecting yield in the cereals, as a phase in the wider question of yield improvement. One of their earliest findings was that the proportion of the seed sown which germinated and produced plants contributing to the harvest yield was much higher than had been supposed formerly; older writers had suggested that this proportion was low, and of the order of 10 per cent., but Engledow has shown that, even under field conditions, it rarely falls below 50 per cent., and that it is often in the neighbourhood of 80 per cent. It follows, therefore, that plant population, and hence yield, is closely related to seed rate and to methods of, and conditions at, sowing.

The close relation existing between plant population and yield is illustrated by the following figures (*loc. cit.*, xvi.); they were obtained from an acre of a good crop of Little Joss wheat, which was sampled by taking 100 foot-rows scattered all over it, and making counts on them throughout the period of growth. Dividing the samples into five groups of approximately equal numbers, the acre may be visualized as made up of the following five parts:

	No. of Plants per Foot-row.	*Average No. of Ears per Plant.*	*Average No. of Ears per Foot-row.*	*Average Weight per Ear (Grms.).*	*Average Yield of Grain per Foot-row (Grms.).*
⅕ acre ..	1-8	2·53	15·1	1·20	18·2
⅕ acre ..	9-10	2·04	19·3	1·19	23·1
⅕ acre ..	11-12	1·91	21·9	1·18	26·0
⅕ acre ..	13-16	1·83	26·8	1·18	31·7
⅕ acre ..	17-24	1·31	24·5	1·16	28·4

As there is a marked rise in yield from the first to the fourth part, and a fall from thence to the fifth, it follows that the yield of three-fifths of the acre was below the potential maximum simply because it was too sparsely occupied, and that a further one-fifth suffered because the plant on it was too thick. Thus, irregularity of plant population

SEED (*Continued*)—

was a severe limiting factor in this good crop; it would be difficult to exaggerate the losses attributable to this cause in many cases.

The intermediate figures show that when the population is too thin, each plant tillers more freely and produces more and bigger ears, but these compensatory influences are insufficient to atone for the basic trouble of sparseness of plant. Tillering, whilst helpful, is limited in its efficacy in evening out the crop, because it is only slightly affected by spacing until comparatively late in the life of the crop (till some critical date, usually in March, but varying with the season), and though a thin population will tiller freely after this period, the tillers produced later will not, in general, live to bring forth ears for the harvest. On the other hand, tillering shows a marked response to nitrogenous fertilizers, and the application of an early top-dressing to provoke free tillering soon enough to give greater numbers of ears, would seem to offer the best chance of overcoming thin spacing; this principle is still under examination. When the plant is too thick, the yield suffers chiefly through the lower average number of ears per plant giving a lower total number per foot-row, and slightly through the diminished size of ear.

This work has shown how important spatial relations are in cereal crops. The problem is slightly different in the case of root crops, for the practice is to sow many more seeds than the population required, and to thin out after germination. Nevertheless, studies on sugar-beet have indicated that the same considerations arise, for, unless the seeding be uniform, even the most skilful thinning will leave a gappy final plant, and this leads to a reduced yield of sugar per acre. (See Sugar-Beet and Mangolds.)

Uniform seeding, therefore, becomes one of the main objects of good husbandry. With cereals it might appear that the final solution would be found in broadcasting, for clearly a reasonably even covering of the whole surface is preferable to restricting the seed to rows, however accurately they are spaced within the rows; broadcasting, though, is unsatisfactory from the point of view of uniform depth of sowing, entails considerable loss from birds, and precludes hoeing. A compromise may be effected by drilling in rows very close together (3 ins.); this is an old practice with grass seeds, and is at present under trial with cereals.

Drilling, as a normal agricultural practice, will probably have to be retained in some form, and hence there is urgent need for a drill that will deposit seed evenly. The common cup-feed type is far from perfect, successive feet of drill-row showing wide variation; thus, counts of the number of seeds actually deposited have given figures varying from foot to foot between 0 and 40, with a standard deviation in the neighbourhood of 6. Unevenness of tilth, as the primary cause of jolts to the implement and thus of variations in the rate of rotation of the seed barrel, plays a part here, but the imperfections of the mechanism, and in particular the variability of the cup load, are responsible for more. Such tests as have been made indicate that the cup feed is at least as efficient as the force feed, but it is still

SEED (*Continued*)—

very unsatisfactory; some new type of delivery is an urgent necessity, and for this to be effective steps will have to be taken to minimize the effects of irregularities of tilth, and to ensure that even distribution is not lost as the seed descends the coulter. To sow the correct average number of seeds per foot with every coulter is not sufficient; each separate foot must receive a number close to this optimum, and, indeed, for the best results those seeds must be distributed evenly over its length, so that not only the number per foot, but also the number per inch, is constant. H. G. S.

SEED TESTING (OFFICIAL), REGULATIONS AS TO*—In the case of a sale of seeds in England and Wales, a statement in writing containing the particulars marked X in the columns on p. 1087 must be delivered to the purchaser *at or before the time of sale or delivery of the seed,* except in the case of a sale of wheat, barley, oats, or rye, for seed on or before April 30 of the year following that in which the seed is harvested, when by virtue of a general licence issued by the Ministry of Agriculture and Fisheries it is sufficient for the declaration to be made within one month of the sale.

Seeds and seed potatoes exposed for sale must have a copy of the prescribed particulars displayed conspicuously on, or in close proximity to, the seeds or seed potatoes.

Seed Potatoes—In the case of a sale of seed potatoes, the particulars to be declared are: (1) Name and address of seller; (2) class—*i.e.*, Class 1 (Scotch), Class 1 (Irish), Class 1 (English once grown), or Class 2; (3) variety; (4) size and dressing.

Packet Seed—The particulars required in the case of a sale of garden seeds do not apply to packets of peas and beans (not exceeding 2 lbs.), or of other garden seeds (not exceeding 8 ozs.), if the following particulars are stated on the packet:

(1) Name and address of seller; (2) that the seeds have been tested in accordance with the Seeds Act, 1920; (3) kind of seed; (4) percentage of purity if below 97 per cent. (90 per cent. in the case of carrot); (5) percentage of germination, provided that if such is at or above the minimum percentage specified in the regulations a statement to that effect is sufficient; and (6) the season in which the seeds were packeted.

Notes to Previous Table—(*a*) Any person who sells, or exposes for sale, or knowingly sows any seeds to which the Seeds Act, 1920, applies, containing more than 5 per cent. by weight of injurious weed seeds, is liable to prosecution in accordance with the provisions of the Act.

The injurious weed seeds for the purposes of the Act are as follows:

Docks and sorrels (*Rumex* spp.).
Cranesbills (*Geranium* spp.).
Wild carrot (*Daucus Carota,* L.).
Yorkshire fog (*Holcus lanatus,* L.).
Soft brome grass (*Bromus mollis,* L. *et spp.*).

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* Ministry of Agriculture and Fisheries, Form No. 728/CS.; by permission of His Majesty's Stationery Office.

SEED (*Continued*)—

Kind of Seed.	*Name and Address of Seller.*	*That the Seeds have been tested in accordance with the Seeds Act, 1920.*	*Country of Origin.*	*Kind of Seed.*	*Distinctive Name of Variety.*	*Purity per Cent. by Weight.*	*Impurities (a).*			*Number per Cent. of Hard Seeds.*	*Total Germination per Cent. by Number.*	*Authorized Minimum Percentage of Germination (n).*
							Total per Cent. by Weight of Injurious Weeds if over 1 per Cent.	*Whether Dodder is Present.* *If more than One Seed in 2 Ozs.*	*If more than One Seed in 4 Ozs.*			
GRASS AND CLOVER SEEDS.												
Perennial rye grass (*b*) ..	X	X	X	X	—	X (*f*)	X (*c*)	—	—	—	X (*g*)	85
Italian rye grass (*b*) ..	X	X	X	X	—	X (*f*)	X (*c*)	—	—	—	X (*g*)	80
Mixture of perennial and Italian rye grasses (*b*)	X	X	X	X	—	X (*f*)	X (*c*)	—	—	—	X (*g*)	82
Cocksfoot	X	X	X	X	—	X	X (*c*)	—	—	—	X	—
Meadow fescue	X	X	X	X	—	X	X (*c*)	—	—	—	X	—
Timothy	X	X	X	X	—	X	X (*c*)	X	—	—	X	—
Crested dogstail	X	X	X	X	—	X	X (*c*)	—	—	—	X	—
Red clover	X	X	X	X	X	X	X	—	X	X	X	—
Alsike clover	X	X	X	X	—	X (*h*)	X	X	—	X	X	—
White clover	X	X	X	X	X	X (*h*)	X	X	—	X	X	—
Wild white clover ..	X	X	X	X	X	X (*h*)	X	X (*d*)	—	X	X	—
Crimson clover	X	X	X	X	X	X	X	—	X	X	X	—
Trefoil	X	X	X	X	—	X	X	—	—	X	X	—
Lucerne	X	X	X	X	—	X	X	—	X	X	X	—
Sainfoin	X	X	X	X	X	X (*e*)	X	—	—	X	X	—
CEREAL SEEDS.												
Wheat	X	X	—	X	X	—	—	—	—	—	X (*g*)	90
Barley	X	X	—	X	X	—	—	—	—	—	X (*g*)	90
Oats	X	X	—	X	X	—	—	—	—	—	X (*g*)	85
Rye	X	X	—	X	X	—	—	—	—	—	X (*g*)	80
FIELD SEEDS.												
Tares or vetches ..	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	90
Mangold	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60 (of clusters)
Swede	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	80
Rape	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	80
Turnip (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	80
Cabbage (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Kale (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Kohl rabi (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Peas (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	80
Beans (field)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	90
Sugar beet	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60 (of clusters)
GARDEN SEEDS.												
Pea..	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Dwarf and broad beans ..	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	75
Runner beans	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60
Parsnip	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	45
Onion	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60
Carrot	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	50
Beet	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	50 (of clusters)
Turnip (garden)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	75
Cabbage (garden).. ..	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Kale (garden)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Kohl rabi (garden) ..	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Swede (garden)	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	75
Cauliflower	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60
Brussels sprouts	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	70
Broccoli	X	X	—	X	—	X (*f*)	—	—	—	—	X (*g*)	60
Flax seed and linseed ..	X	X	X	X	—	X	—	—	X	—	X	—
Forest tree seeds (*m*) ..	X	X	X	X	—	X	—	—	—	—	X (*k*)	—

SEED (*Continued*)—

(*b*) In the case of the rye grasses the imperial bushel weight must also be declared.

(*c*) In the case of the grasses the total percentage by weight of injurious weed seeds must be declared when over 2 per cent.

(*d*) In the case of wild white clover, dodder must be declared if present to an extent of more than one seed in 1 oz.

(*e*) Where burnet is present in sainfoin to an extent of more than 5 per cent. by weight, the exact percentage present must be declared.

(*f*) If the percentage of purity in the case of the rye grasses is not less than 98 per cent., a statement to that effect is sufficient, and in the case of the field and garden seed the purity need not be stated unless it is below 97 per cent. (or 90 per cent. in the case of carrot seed).

(*g*) If the germination is not less than the authorized minimum percentage of germination prescribed in the Seeds Regulations, 1922, a statement to that effect, which shall include the authorized minimum percentage, is sufficient.

(*h*) If the percentage of suckling clover (*Trifolium dubium*, Sibth.), hop clover (*T. procumbens*, L.), *T. parviflorum* Ehrh., *T. angulatum* Waldst., and *T. glomeratum* L. exceeds 2 per cent. by weight, the exact percentage must be declared.

(*k*) The percentage of germination need not be declared in the case of the broad-leaved kinds of forest tree seeds.

(*m*) In the case of forest tree seeds the year and the months of collection must also be declared.

(*n*) Seeds with a germination of less than the authorized minimum percentages may be sold provided the actual percentage of germination is declared.

Provisions as to Tests for the Purposes of the Seeds Act, 1920—Except in the case of garden seeds, tests for the purposes of the Seeds Act must be made either at one of the Official Seed Testing Stations, or at a private Seed Testing Station licensed by the Ministry. Licences for private Seed Testing Stations are granted solely for the purpose of the licensee's own purchases and sales.

Where seeds are sold or delivered or exposed for sale at any time other than some time within the months of August or September, the test for the purposes of the Act must be made not earlier than August 1 last preceding, and, where seeds are sold or delivered or exposed for sale at any time within the months of August or September, the test must have been made not earlier than August 1 in the previous year.

Exemptions—The Seeds Act does not apply to a sale of seed under the following conditions:

(*a*) When sold to a person "purporting to purchase them with a view to cleaning them before they are sold or exposed for sale."

(*b*) When the purchaser at the time of the sale gives the seller "an undertaking in writing that he will before selling or exposing

SEED (*Continued*)—

the seeds for sale test or cause them to be tested, or that he will not resell the seeds to a seed merchant except on a similar undertaking by the purchaser."

This exemption is made to cover a sale of seeds through a "string" of merchants. It enables such seed to be passed from merchant to merchant without the necessity of a statement containing the prescribed particulars being delivered in each case.

(*c*) When sold for delivery outside the United Kingdom; and
(*d*) When sold for some purpose other than for planting or sowing.

The Official Seed-Testing Station for England and Wales—Seed Merchants and Farmers sending samples of seeds to the official station for test must comply with the following regulations:

Method of Sample Taking and Size of Sample of Seeds that will be Tested—A sample sent for a test on which a declaration is to be based must be drawn in accordance with, and must be of not less than the weight specified in, Regulation 5 of the Seeds Regulations, 1922.

The weights are as follows:

	Not less than
Garden swede, garden turnip, garden cabbage, garden kale, garden kohl rabi, brussels sprouts, broccoli, cauliflower, carrot, parsnip, onion	¼ oz.
Wild white clover	1 oz.
Rye grasses, meadow fescue, cocksfoot, crested dogstail, timothy, alsike clover, white clover (other than wild), field turnip, swede, rape, field cabbage, field kale, field kohl rabi, mangold, beet, and sugar beet	2 ozs.
Wheat, oats, barley, rye, tares or vetches, red clover, crimson clover, trefoil, lucerne, sainfoin, flax, linseed, and mixtures of grasses and clovers	4 ozs.
Peas (field and garden), beans (tick and winter), dwarf beans ..	4 ozs.
Broad beans, runner beans	8 ozs.
Menzies or Sitka spruce	1 oz.
Hemlock spruce, red or canoe cedar	½ oz.
All other kinds of forest tree seeds	2 ozs.

Sealed packets of seeds. Such number of unbroken packets as together contain the minimum weight above prescribed, but not exceeding three unbroken packets.

The official Seed-testing Station for Scotland is at East Craigs, Corstorphine, Edinburgh, and for Northern Ireland at Belfast. (See Seed Control.)

SEED, TRANSMISSION OF PLANT DISEASES BY—Although in plants there may perhaps be a few functional disorders (ordinary *Chlorosis*, for example) comparable to those that occur in man and other animals, yet by far the greater number of diseases of crop plants result from the attacks of specific parasitic organisms. Occasionally these parasites are other higher (*i.e.*, flowering) plants, such as Mistletoe, Dodder, Broom-rape, etc.; but, generally speaking, they are lowly organisms belonging to the groups of Fungi, Bacteria, Slime-fungi, and Nematodes, the first-named being decidedly the most frequent and important. In comparatively recent years Viruses have had to be added to this

SEED (*Continued*)—

list, although we are still in the dark as to what Viruses really are; they may not be organisms at all. Plant diseases due to such agencies may be looked upon as "infectious," and the sources from which the infection may come are matters of great importance, particularly when the possibilities of prevention or control come to be considered. Damage done to plants by the depredations of insects or other animal pests (apart from Eelworms) does not come within the scope of the present article.

The infective material giving rise to a plant disease of the kind under consideration must, of course, be a living part of the parasite itself, although occasionally it may be the whole parasite. As a rule the part concerned is that ordained by the parasite for its own multiplication, survival, or dispersal. In parasitic flowering plants this is the seed; in the more lowly organisms it is usually a more or less equivalent body called the spore. In bacteria it may also be a spore, but it is nearly always the whole organism. In Nematodes (eelworms) it may be the worms themselves, or their eggs.

Amongst the fungi many different forms of spores are produced, and one and the same fungus may produce spores of several different kinds. Some of them are delicate and short-lived, not being able to withstand such adverse conditions as absence of moisture or too high a temperature. Others, sometimes called "resting spores," are sturdy and resistant, and can, in some cases, retain their vitality under adverse circumstances for very long periods. Many fungi produce bodies called *sclerotia.* These are compacted masses of fungus spawn (*mycelium*) often about the size of an ordinary seed and well provided with reserve food. They enable the fungus to survive unfavourable periods, whilst, by becoming transported from place to place, they secure its distribution. From the points of view of survival and distribution, a sclerotium may be compared with a bulb, corm, or tuber of a flowering plant; and sclerotia often play a very important part in the origin and dispersal of plant diseases.

The parasite may sometimes invade any or all of the organs of the host plant, but usually the actual seat of attack is more or less restricted. Thus, in Finger-and-Toe (or Club Root) disease of cabbages, turnips, and other Cruciferous plants, it is the parts of the plant underground that are mainly affected; and, although the consequences of such attack are seen well enough also in the overground parts, yet the parasite itself does not reach these parts. Again, infection may be confined to the aerial parts of the plant, and sometimes to particular organs. Thus, the fungus that causes apple and pear Canker (*Nectria galligena*) most commonly attacks the stems, less frequently the fruit ("Eye-Rot"); but the leaves remain free from the parasite. On the other hand, all the overground parts of a plant may become infected in some instances, as, for example, with Celery Leaf Spot or Blight. Here stems, leaves, flowers, and fruits may not merely become infected, but may bear the spore-producing parts of the fungus.

In flowering plants the seed—using the term in its strict botanical sense—is always developed within the fruit—as, for example, a pea in

SEED (*Continued*)—

the pod. This being so, it might be supposed that seeds would remain protected from infection by fungi or other parasites; yet this is not always the case. The pod may become infected by a fungus, for example, and the mycelium may grow through the wall of the pod and into a seed that is lying against the inner side of the wall; in this way the seed itself becomes infected. Moreover, in a few cases the seed may be the organ primarily attacked, as in the Loose Smuts of wheat and barley. Here the spore germinates upon the feathery stigmas of the young ovary, and the resulting mycelium penetrates into the interior of the incipient seed. This, however, does not materially affect the development of the seed, or of the grain which encloses it; and the grain, when ripe, contains the dormant spawn of the parasite hidden in its very heart.

Very often what the farmer or gardener sows is not the true seed in its limited, botanical sense, but is a more or less complex structure consisting of the true seed together with certain other parts of the plant that have remained in union or have become united with it, the whole comprising what might be termed the plant's "unit of dispersal." The "seeds" of many plants are one-seeded fruits, as in wheat; in other plants they may be one-seeded half-fruits, as in carrot, celery, and parsnip. Again, each "seed" may consist of a united cluster of several one-seeded fruits, as in mangold and beet. It is clear that in such cases the exterior of the "seeds" may be exposed to air-borne infection from spores just as leaves and stems are; and that "seeds" of this kind, when they leave the plant, may carry a parasite with them, although it need not necessarily be within the true seed.

There are some plant diseases in which the seed becomes invaded by a fungus that reaches it not from spores deposited from the air, but by mycelium entering directly from the mother plant. Bunt of wheat, Covered Smut of barley, and the Smuts of oats are examples in which this type of infection occurs. In these cases, however, the seed does not develop; in its place the fungus produces enormous numbers of its own spores. When the thus aborted seed becomes broken open, the spores are liberated; and, being very small and dust-like, many of them adhere mechanically to the exterior of uninfected seeds that may be near them. This occurs particularly during the harvesting and thrashing of crops of bunted wheat or of barley affected with Covered Smut, or of crops of smutted oats.

Lastly, although seeds, if left to themselves, may not become either infected or contaminated as described above, yet, when saved artificially by man for his own use, they may become associated with material carrying a parasite or even with a parasite itself. Fragments of the parent plant carrying perhaps the resting stage of a fungus may be present along with the harvested seed, as sometimes happens with flax seed and the resting stage of its Rust fungus. Again, sclerotia may accompany seed, as, for example, the Ergots of rye; whilst if the parasite is a flowering plant, like Clover-Dodder, it is practically impossible to harvest the seed of an attacked crop of the host without admixture with seed of the parasite. The so-called "ear-cockles"

SEED (*Continued*)—

of wheat also come into this category. It is well to remember that the "impurities" in the seed that a farmer or gardener sows may consist not only of other seeds (including those of weeds), dirt, and various other forms of débris, but also of the seeds or other parts of actual parasites, capable very often of causing disease in the resulting crop. When considering the "purity" of a sample of seed as determined at a Seed Testing Station, therefore, that farmer or gardener is wise who pays attention to the *nature* of the impurity present (if any), as well as to its amount. (See Seed Control.)

From what has been said above, it will be clear that the possibilities of inaugurating disease in a crop by transmitting the causative agent along with the seed sown are many and various, and it will perhaps be advantageous at this stage if these possibilities are arranged in categories and summarized in tabular form as follows:

I. INFECTED SEED	(1) Parasite wholly within the interior of the seed, *i.e.*, intraseminal.
	(2) Parasite mainly within the seed, but usually near the surface or partly exposed, sometimes producing fructifications thereon.
II. CONTAMINATED SEED	(3) Parasite wholly external, adhering mechanically (generally in the form of spores) to the exterior of the seed.
	(4) Parasite neither within nor on the seed, but merely accompanying it in bulk.

Some examples from each of these four groups will now be considered, and ways and means of preventing outbreaks of diseases from these sources mentioned. The groups will be considered in the reverse order to that given above.

As examples of Group (4) may be taken Dodder, Ergot of cereals, and the Eelworm disease of wheat ("cockles"). Dodder (*Cuscuta*) is a flowering plant belonging to the Convolvulus or Bindweed family. Its importance in agriculture is confined almost entirely to crops of clover and flax, and its seed occurs in commercial lots of these seeds, frequently in clover and more rarely in flax. When the small, round, light-brown seed germinates, the resulting seedling resembles a small white worm. It has no roots, but possesses a certain limited power of movement (circumnutation). When this seedling comes into contact with its proper host it twines around the stem and sends suckers into it, thereby feeding itself at the expense of the host. Growth proceeds rapidly; the wiry stems of the Dodder extend and branch in all directions, and all the time coil round and send suckers into the host plant, exhausting its strength until it may be smothered out of existence altogether. No wonder the Dodder is sometimes called the "Devil's Thread"! Meanwhile the parasite flowers and produces seed, which is harvested with that of the crop; and, unless previously eliminated, is sown again with it.

An Ergot is the sclerotium of a genus of fungi known as *Claviceps*, that attacking rye being called *C. purpurea*; it is formed in the ear of a cereal or a grass instead of a grain, and is usually about the same

SEED (*Continued*)—

size as the grain or a little larger. Ergots not infrequently accompany the seed of grasses and grain, particularly rye, much less commonly wheat. Incidentally, they contain a poisonous principle; and if a cereal containing Ergots is ground into meal or flour, and then used for making bread or other food, the result, when this is eaten, may be very serious indeed. An Ergot either falls to the ground from the ear in which it is formed or else is harvested with the seed, in which case, unless precautions are taken, it will reach the soil once more. In early summer the Ergot in the soil germinates by sending up little drumstick-like structures, in the spherical heads of which conceptacles arise which contain spores. When ripe, the thread-like spores are ejected into the air and are carried by currents to the feathery stigmas of cereals which are exposed for the purposes of pollination. There they germinate, and, as a result, the incipient grain becomes infected with the fungus. Eventually, after a series of changes that cannot be described here but amongst which is provision to secure more widespread infection, a new Ergot arises instead of a grain; and so the cycle is completed.

Just as Ergot sclerotia may accompany seed of the host plant, so may other sclerotia, although they are not necessarily produced in the floral parts of the host. The sclerotia of the fungus that causes Rot of Red Clover (*Sclerotinia Trifoliorum*) are an example, while another interesting one was reported a short time ago in which many of the seeds in a consignment of white clover imported from New Zealand became partially or wholly converted into sclerotia which, on germination, produced typical fructifications ("apothecia") and spores of a species of Sclerotinia (Alcock and Martin, *Trans. and Proc. Bot. Soc. Edinburgh*, xxx., p. 13, 1928). The sclerotia of certain species of Typhula that cause diseases in grasses and cereals, as well as in mangolds and sugar beet, may also be mentioned, as they sometimes accompany the seed although they are not common in this country. Finally, it may be mentioned that fragments of the host plant carrying the black, resting-spore stage ("teleutospores") of the flax Rust fungus (*Melampsora Lini*) may sometimes be found in flax seed.

In seed wheat darkish bodies, rather smaller and rounder than the true kernels, sometimes occur which, at first sight, might be thought to be weed seeds. If, on being crushed, they yield a black mass of fungus spores, they are the so-called "butts" of the Bunt fungus, which will be considered later on. Rather smaller and harder ones, when crushed and examined under the microscope, will be found to be composed of myriads of minute young worms—Eelworms or Nematodes; these constitute the so-called "ear cockles," "purples," or "peppercorns" of wheat. When the "cockle" reaches the soil with the seed grain its walls soften and the young worms come out. They migrate to the young wheat plants, enter them, and proceed to the regions of the growing points of the shoots. The attacked plants are stunted and show wrinkled leaves with curly edges, but do not necessarily die. Some, at any rate, produce ears that are usually shorter and thicker

SEED (*Continued*)—

than healthy ears, and in them a new crop of "cockles" arises. Many of the "cockles" fall to the ground and contaminate it, but many are harvested and threshed with the wheat. In the dry, "cockle," stage the worms may remain alive for a considerable time, even up to as many as nine years.

As to remedial measures, in contaminations of the kinds described the farmer is largely in the hands of the seed supplier; but with modern machinery it is possible so to clean most kinds of seed that disease-carrying material is eliminated. If this cannot be done such contaminated seed should not be used for sowing purposes. As to "cockles," a fairly simple way of removing these is to place the contaminated grain in a 20 per cent. solution of common salt, or brine, taking care to stir the whole well. The grain, being heavy, will sink; but the lighter "cockles" will float on the surface, and can be skimmed off and destroyed, the thus purified grain being afterwards washed, drained, and dried. The salt has no adverse effect on the vitality of the grain. In England this disease is much more prevalent in the south-west than elsewhere, and it is also fairly common in south Wales.

As examples of contaminated seed falling into Group (3), *i.e.*, seed with the parasite adhering mechanically to the surface, the Covered Smuts of wheat (Bunt) and barley may be taken, and also the two Smuts of oats. In all of these diseases the plant becomes infected when very young and whilst still underground. The fungus, having entered the seedling, grows up within the developing plant, but causes no very material change in it until the grain begins to develop. Then, where the grain should be, a black mass of spores is produced, giving rise to the smutty ears characteristic of the disease. Seed derived from a smutted crop will be accompanied not only by "butts," *i.e.*, unbroken bunted grains in wheat, or by fragments of the smutted ears in barley and oats, but also by spores, which will be adhering to the surface of the grain. In Bunt of wheat this is the condition when the grain is ready for sowing, but probably in barley and also in oats the spores, or some of them, may be lying between the pales and the kernel or may, by harvest time, have germinated and produced a certain amount of mycelium there. This mycelium may even have invaded these structures superficially to some extent, and such cases should perhaps more properly be included in Group (2); at any rate, they form a transition between Groups (3) and (2).

To obviate the transmission of these diseases through the contaminated seed suitable treatment must be undertaken. Mere mechanical cleansing will do much to remove the infective material from bunted wheat. Steeping or washing in water alone, for example, will remove the lighter "butts" and most of the adhering spores, but it is preferable to use a fungicidal solution; this, if efficient, will kill the spores that may not be washed off the grain, but it will not kill the spores in unbroken "butts," since the solution does not penetrate them sufficiently; a suitable fungicide will also kill any superficial or semi-superficial mycelium that may be present in barley and oats. Such treatment of the grain is known as "pickling." The materials

SEED (*Continued*)—

hitherto most often used for pickling have been dilute solutions of copper sulphate (bluestone) and formaldehyde (formalin), the latter being the more effectual, perhaps, of the two. Limits of space preclude discussion of the details of the "pickling" process here, but they will be found in the various textbooks on plant diseases and in numerous bulletins and leaflets prepared for the use of farmers. Under some conditions, and especially if the pickling process is carelessly carried out, the vitality of the grain may suffer injury; and, during recent years the dusting of contaminated cereal grain with a finely divided fungicidal powder has come much into vogue, the practice having originated in Australia (Reynolds, *Agric. Gaz. N. S. Wales.*, xxiv., p. 461, 1913; Darnell-Smith, *ibid.*, xxvi., p. 242, 1915; xxviii., p. 185, 1917; xxx., p. 685, 1919; xxxii., p. 796, 1921; xxxiii., p. 754, 1922). Copper carbonate in finely powdered form has largely been used for the purpose and with much success, at least so far as Bunt in wheat is concerned (Pethybridge and Moore, *J. Min. Agric. and Fish.*, xxxvii., p. 429, 1930-31); it would appear to be less efficacious for Covered Smut of barley and the Smuts of oats. Numerous other powders have been put on the market lately, and many of them contain organic compounds of mercury. They are usually sold under fancy names, are perhaps rather dearer than copper carbonate, while the handling of them involves some risk to the operators, since many of them are poisonous. Even copper carbonate is not pleasant to get into the eyes, nostrils, or throat; and even when a suitable dust-tight machine is available for treating the seed, it is difficult to avoid the distribution of some of the dust into the air when filling the sacks from the machine. Efficient dusts have this advantage—namely, that some further contamination after treatment is of little or no consequence; the fungicidal action takes place not during treatment, as occurs when the grain is "pickled" in the wet way, but only or mainly in the damp soil after the seed has actually been sown. The most recent work shows, however, that with certain powders, fungicidal action may set in even within a few hours after treatment, and before the seed is sown (E. Hiltner, *Angew. Bot.*, xii., p. 352, 1930). With fungicidal dusts or powders there is little or no danger of injury to the vitality of the grain, but with very heavily contaminated seed they are not quite so efficacious in suppressing Bunt as are the liquid fungicides. Another advantage of the dry treatment is that the dusted grain does not suffer if sowing is delayed and it has to be stored.

Other examples of seed contaminated by the mechanical adhesion of the parasite to its exterior could be furnished, but two more must suffice, both being concerned with bacterial diseases of plants. Black Rot of cabbages and other Cruciferous crops is a disease of this kind, and is caused by *Pseudomonas campestris*. It does not occur very frequently in this country, but appears to be fairly common in the United States of America. Although the seed of the diseased host may not itself become directly invaded, yet during seed saving and cleaning operations it may come in contact with affected parts of the host, and the bacteria in them may be transferred and adhere to the

SEED (*Continued*)—

more or less oily seed coat. There they may remain in viable condition for many months. Disinfecting the seed by soaking it for about half an hour in a dilute solution of mercuric chloride (corrosive sublimate), or keeping it for the same period in water heated to 122° F., have proved to be satisfactory methods of preventing seed transmission of this disease, although the germination of the seed may be considerably lessened by the hot-water treatment. A second disease of similar type is the so-called "Angular Leaf Spot" (or "Black Arm") disease of cotton. Formerly it was thought that the causative organism, *Bacterium Malvacearum,* occurred here intraseminally; but recent research has shown that this is not so (Stoughton, *Nature,* cxxv., p. 350, 1930). Appropriate treatment of the contaminated seed with sulphuric acid satisfactorily disinfects it.

Passing now from the two groups of contaminated seed to those in which the seed is actually infected with the parasite, examples coming into Group (2) may first be considered. Here it is the superficial tissues, mainly, that are invaded, consequently the parasite is still in a comparatively vulnerable position. Sometimes its spore-bearing fructifications are developed and exposed, as with the fungus that causes Celery Leaf Spot or Blight (*Septoria Apii*). The mycelium of this develops in the wall of the seed (a "half-fruit") and produces minute conceptacles called pycnidia. In them large numbers of minute spores are produced which, when ripe, are extruded through a small pore, provided that sufficient moisture is present. On germination of the seed, the seed coat is often borne aloft above ground on the cotyledons; and by means of the spores exuded from the pycnidia on it, one or both of them may become infected. Soon afterwards pycnidia are formed on the cotyledons, and a single diseased celery seedling may thus form a centre from which an epidemic may ultimately arise. Very much the same kind of thing occurs in one of the diseases known as Black Leg of mangold and sugar beet. Here the pycnidia of *Phoma Betae* are partially embedded in the seed, and, on germination, infection of the young roots readily occurs. Again, in the Leaf and Pod Spot disease of peas, generally associated with the fungus *Ascochyta Pisi,* something of a similar nature occurs; for, although, at the time of sowing, no pycnidia may be present on the seed coats, yet they arise there from dormant mycelium and deliver their spores a few days after the seed has been kept damp; and from these spores the young seedling can become attacked.

The diseases of flax, "Seedling Blight" due to *Colletotrichum linicola* and "Browning" (and "Stem Break") due to *Polyspora Lini,* are transmitted by infected seed, the mycelium of the fungi concerned having entered the seed coats through the walls of the attacked fruit capsules, and become dormant in the seed coat (Pethybridge and Lafferty, *Sci. Proc. Roy. Dublin Soc.,* xv., p. 359, 1918; and Lafferty, *ibid.,* xvi., p. 248, 1921). Again, the Foot Rots and Blights of cereals, caused by certain species of Fusarium, such as *F. avenaceum* and *F. culmorum,* may arise from mycelium more or less dormant in the tissues of the seed grain. Many other examples could be brought

SEED (*Continued*)—

forward; indeed, probably the greater number of cases of seed transmission of disease fall into this group; but space does not permit of dealing with them here. One particularly interesting example, however, may be alluded to that has only quite recently been investigated thoroughly. It is the Leaf Stripe disease of barley, due to *Helminthosporium gramineum*. Formerly this parasite was supposed to be systemic in the plant, like the cereal Smut fungi, but it has now been shown that this is not the case (N. J. G. Smith, *Ann. Appl. Biol.*, xvi., p. 236, 1929). Pickling the infected grain with corrosive sublimate or with one of the newer organic mercury compounds has given fairly satisfactory control. The corresponding disease of oats, due to *H. Avenæ*, and also transmitted by seed, has recently been the subject of detailed study in Scotland (O'Brien and Prentice, *Scot. J. Agric.*, xiii., p. 272, 1930) and in Germany (H. Rathschlag, *Phytopath. Zeitschr.*, ii., p. 469, 1930).

Preventing the occurrence of outbreaks of disease from such infected seed may at first sight seem a comparatively simple matter; the seed need merely be pickled, or disinfected, in such a way that the fungus is killed without injury to the seed. There are, however, difficulties in certain cases, and each must be dealt with in the light of its own peculiar circumstances. For example, celery seed treatment with dilute formalin was, for many years, regarded as effective. But recently it has been shown that although the spores already formed may easily be killed, yet the pycnidia themselves are not, unless the formalin is so strong or the time of steeping so long that the germination of the seeds is thereby seriously diminished. After treatment, and when the formaldehyde gas has diffused away, the pycnidia may produce fresh crops of spores, and from them the disease may arise after all! (Stirrup and Ewan, *Min. Agric. and Fish. Bull.* 25, 1931). In a case like this the true solution of the difficulty is to grow a clean seed crop, and it has been shown that this is really a practicable and a paying proposition. It is difficult to pickle such seeds as those of flax, because they become mucilaginous when wetted, and tend to cake together into lumps. However, it has been shown, on a small scale at any rate, that this can be overcome by subsequent drying with the aid of a suitable powder. Treatment of seed with dry fungicidal powders is now coming greatly into vogue, but this or any other treatment is on the face of it likely to be less successful with infected seed than with merely contaminated seed, and too much must not be expected of it.

Examples coming into Group (1) remain to be considered, and fortunately they are few, the best known being the Loose Smuts of wheat and barley. The mode of infection here has already been touched upon; it is "floral"—via the stigmas, as opposed to "seedling"; via the first formed leaf whilst still underground,* as in Bunt and Covered Smuts; and the fungi concerned are present as dormant

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* There is evidence that infection of barley with Loose Smut may also occur, under some conditions, in the seedling stage (Tisdale and Tapke, *J. Agric. Res.*, xxix., p. 263, 1924).

SEED (*Continued*)—
mycelia entirely within the seed. The idea that cereal Smut infection might take place through the flowers occurred to Hoffman as long ago as 1866, and was considered but dismissed by Jensen more than twenty years later. But it does happen, and it is not perhaps very generally known, that the actual occurrence of this "floral" mode of infection with Loose Smut was first practically demonstrated in wheat, and was described in a short pamphlet by Mr. F. Maddox, a Tasmanian farmer, in 1895 and 1896 ("Experiments at Eastfield," *Dept. Agric. Tasmania*, 4 pp., 1895; also "Diseases in Wheat," Sydney, 1928). Yamada and Nakagawa, in 1896 and 1897 respectively, demonstrated the same thing, so that Hecke's and Brefeld's work, published in quarters more readily accessible to most scientific workers, some eight or nine years later, was a rediscovery of this process, and furnished greater details of it. When the infected grain germinates the mycelium of the fungus continues to grow within the developing plant, and ultimately enters the young grain of plants that survive, destroying it, and producing in its place a mass of black spores.

In Ergot of cereals and grasses infection of the incipient seed through the agency of spores that alight on the stigmas also occurs. But here the seed is doomed at the outset, and instead of it a sclerotium (Ergot) is formed.

Attempts to kill the parasite, without injuring the seed, by heating the grain in a dry condition have met with little or no practical success. On the other hand, if the infected grain is first allowed to swell for a period in lukewarm water and then plunged for a certain limited time (about ten minutes) in hot water at a temperature of approximately 52° C., the parasite appears first to awake from its dormancy, and, as a result, to become more sensitive to a further rise of temperature. In that condition the rapidly following short hot-water treatment is sufficient to kill it, and that without serious injury to the grain itself. The method appears simple enough, but in actual practice there are several difficulties to be overcome; for, if the water be too hot, the grain may be seriously injured, whilst if not hot enough, the fungus may be encouraged rather than destroyed. *The best way of avoiding these Loose Smuts is to refrain from the use of grain from a loose-smutted crop for seed purposes.*

In connection with Group (1) must lastly be considered the question of the transmission of Virus diseases of plants through the seed. These diseases are believed to be caused by what Beijerinck, in 1899, called a *contagium vivum fluidum*, and not by parasitic organisms; at any rate, not by organisms of the relatively gross dimensions possessed by fungi or by ordinary bacteria. (See Virus Diseases, and Potato, Virus Diseases of.) The infective principle—the Virus, whatever it may ultimately prove to be—is capable, in general, of passing through the exceedingly minute pores of certain types of filters (*e.g.*, unglazed porcelain) that will not permit the passage of the smallest known micro-organisms. Virus diseases, such as the different kinds of Mosaic, Leaf Roll, etc., are generally regarded as being systemic; that is, the infective principle is considered to be more or less uniformly

SEED (*Continued*)—

distributed throughout the whole of the living tissue of the affected plant. It is true there are a few exceptions in which there appears to be some localization of the Virus, even in parts of the vegetative organs of the plant; but these cannot be discussed here. It seems fairly certain, also, that in many cases the Virus is not present in the seed, for many Virus diseases do not appear to be seed transmitted. Much further research on the problem is required, however, and it may be true that an occasional seed derived from a plant affected with Mosaic, or some other Virus disease, does give rise to a plant similarly affected. Bewley and Corbett (*Ann. Appl. Biol.*, xvii., p. 260, 1930), for instance, have recently brought forward evidence leading them to believe that both the Mosaic of tomato and that of cucumber are transmitted by the seed, and they find that these diseases can be reduced to small proportions, if not entirely eliminated, by the exclusive use of clean seed. A Mosaic of lettuce also appears to be seed transmissible, whilst seed transmission of the Mosaic diseases of several kinds of leguminous plants, such as beans, peas, and clovers, appears to occur to a certain extent with considerable regularity. On the other hand, Mosaic diseases are very common in the family Solanaceæ, and here seed transmission seems to be the exception rather than the rule. The evidence so far obtained in regard to seed transmission of Mosaic in beet has been entirely negative, whilst American work has shown that the Mosaic of cucumbers and other cultivated cucurbits is either not seed transmissible or is so rarely transmitted as to be of little significance. On the other hand, the Mosaic of the American wild cucumber (*Micrampelis lobata*) is transmitted through the seed; and the disease is conveyed from affected wild plants to cultivated cucurbits through the agency of certain insects.

As to ways and means of preventing the transmission of virus diseases through the seed where it does occur, apart from the use of seed derived solely from healthy plants, nothing has yet been worked out.

Sufficient has now been said concerning the *possibilities* of the transmission of plant diseases in consequence of the more or less intimate association of the seed of the host with a pathogenic organism, and the examples considered so far have been, in most instances, cases in which such transmission is known to take place with considerable regularity. It must, however, clearly be borne in mind that the mere association of seed and parasite does not necessarily connote or involve disease transmission. Some two hundred or more instances are now known in which the seeds of diseased plants become associated in one way or another with the specific pathogen; but only in some of these cases, perhaps about half, has conclusive experimental evidence been brought forward to prove that disease transmission actually does occur as a result of this. In every presumptive case, unless and until indisputable evidence has been secured to convict it, the seed must be held to be not guilty; otherwise purveyors of seed may be blamed unjustly, or time and money may be wasted in carrying out unprofitable seed treatment.

SEED (*Continued*)—

One very important example of the non-transmission of disease, in spite of occasional seed infection, may be alluded to here. The carrying over of certain of the cereal Rust fungi from one season to the next in some countries was for a long time a matter very difficult to explain. It was obvious to think of seed transmission; and, as a matter of fact, pustules of the Black Rust fungus (*Puccinia graminis*) and of the Yellow Rust fungus (*P. glumarum*) have been discovered by more than one observer on seed grain, although such infection is by no means common. Nevertheless, experimental attempts to produce plants affected with Rust from infected seed have always given negative results when all other possible sources of infection have rigidly been excluded; and the cereal Rusts, therefore, are not believed to be seed transmitted.

It must also be remembered that even in cases where seed transmission of a disease has been proved generally to occur, it does not necessarily follow that such transmission must inevitably, and under all conditions, take place. A disease is the resultant of three interacting factors: the host, the parasite, and the environmental conditions to which both are subject. Cases are known, for example, in which grains of wheat, although contaminated with Bunt spores, have not produced bunted plants when sown. This may have been because the environmental conditions were such as to preclude the occurrence of infection, or because they inhibited the usual development of the fungus within the host tissues, so that it did not culminate its growth by entering the grain and forming spores there. Such cases, however, are rare; and their occasional occurrence should not lead the grower to neglect proper treatment of his seed when it is known to be infected or contaminated by a transmissible parasite.

Again, a seed carrying a parasitic fungus may itself already be dead; and the chances of disease transmission when sown would, generally speaking, be negligible. On the other hand, the parasite on the seed may have lost its vitality, and thus the seedling might escape infection. It is commonly believed, for instance, that *Septoria Apii,* the fungus that causes celery Leaf Spot or Blight and produces its pycnidia on the seed, dies as the seed ages; and that old celery seed, therefore, although it may still carry the fungus, may safely be used for sowing, in the expectation that none but healthy seedlings will arise from it. As a matter of fact, this fungus does die off to some extent on the seed, and of course the seeds themselves also die as they become aged. But it has recently been proved by experiment that old celery seed affected with *S. Apii* is not safe, for on some of it the fungus still remains viable and capable of infecting the developing seedlings, thus providing a focus for a subsequent epidemic in the crop.

It must also not be forgotten that in many cases the seed is not the sole source from which a particular disease may arise in a crop, and therefore the seed must not bear the whole blame unless the other possible sources of infection have entirely been excluded. *Phoma Lingam* is a parasitic fungus that causes the disease known as Dry Rot in swede roots, and that known as Canker in the basal parts of the stems

SEED (*Continued*)—

of swede mother-plants grown for seed production. The fungus also produces spots on the leaves and on the "pods" (*siliquæ*), and it may penetrate the walls and reach and invade the coats of some of the seeds. It has been proved experimentally that such infected seeds can give rise to diseased seedlings. However, the percentage of infected seeds in commercial lots is usually quite small, perhaps about four or less in a thousand. In New Zealand, Dry Rot of swedes is an extremely common and serious disease. There, it is maintained, infected seed is the sole source from which infection of the crop arises. In England, on the other hand, the observations made in recent years lead to the belief that seed transmission of this disease is relatively rare, and that infection from the seed bed, from some previously diseased neighbouring crop or from some other such source, is far more common, or at any rate far more important. This particular example is mentioned here in order to show that it may be by no means always an easy matter to decide, even where seed transmission of a particular disease is a proved possibility, whether a specific outbreak can be ascribed to the sowing of infected seed or to some other cause.

Everyone who has had experience in the testing of seeds for germination knows how frequently fungi develop on the seeds whilst they are under test. Some of these fungi may be certain of the parasitic forms that have been discussed above (*e.g.*, species of *Fusarium* on cereal grains, *Ascochyta* on peas, etc.); others, however, often classed as "moulds" (*e.g.*, species of *Penicillium*, *Mucor*, etc.), are generally regarded as saprophytes—that is, as being incapable of infecting living plants. Nevertheless, no one knows better than the Seed Tester how essential it is to be scrupulously microbiologically clean in his work if the germination tests are to give the highest possible results. Moulds are frequent on seeds, and whilst they may not perhaps give rise to specific diseases, yet their presence and development during the germination phase may produce an unsatisfactory seedling-environment, which militates against normal and vigorous growth. It is perhaps because such undesirable agencies are suppressed when seeds are treated with certain fungicidal solutions or dusts before sowing that the resulting plants sometimes appear as if the treatment had acted as a direct stimulus to their growth.

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G. H. P.

"SEEDS" HAY—For composition and feeding value see Feeding Stuffs.

SEEDS MIXTURES—There is no finality to the subject of seeds mixtures. Little more than a century ago the bulk of this country's seed supply was derived from well-harvested hay crops. Such material, frequently containing a high percentage of injurious weeds, had to do service for all purposes. To-day machine-cleaned seeds of all the suitable clovers and grasses are easily obtainable separate, and with known purity and germinating capacity.

Pure stocks of home-grown seed, and the regular arrival of foreign-grown varieties, have not been the only influences which have altered the compositions of mixtures for laying down land to grass in this country. Valuable information has gradually accumulated from carefully conducted field trials on the better adaptation of available varieties, while the late Professor Gilchrist proved the outstanding value of wild white clover, the seed of which was hardly obtainable commercially at the time his experiments were initiated at Cockle Park.

Within the last ten years botanists and plant breeders have produced stocks of better feeding value. Their work has shown how, by employing varieties giving their highest feeding value at different times, the grazing period of pastures can be regulated and extended; more

SEEDS MIXTURES (*Continued*)—

recently still, the biochemists and physiologists, by their investigations into the chemical composition of herbage from both good and bad pastures, have introduced yet another influence which may affect the composition of seeds mixtures in the future. (See Foods and Feeding.)

And so it may be truly said that the evolution of more serviceable seed mixtures marches side by side with scientific investigation. It is, indeed, only by combining local influences with the improvements brought to light by up-to-date research that we can hope to obtain the maximum satisfaction from our leys, be they for long or short duration.

The following is a list of the most important varieties of clovers and grasses employed in present-day seeds mixtures in the British Isles:

Clovers—*Broad-Leaved Red Clover*—An early quick-growing clover which grows rapidly again after cutting. It forms the basis of mixtures for one-year leys for hay, especially where it is intended to take two cuts.

Late-Flowering Red Clover—A late variety, flowering about a fortnight later than broad-leaved red. It gives a heavier yield of hay but not so good an aftermath; it is more persistent than the early red and so more useful for long leys.

Alsike Clover—This clover grows successfully under a wider range of climatic conditions than red clover; it withstands both wet and cold and gives bulk to hay crops.

White Clover—(*a*) *Dutch White.* This variety is essentially a short-ley pasture clover. It comes to maturity earlier than wild white and produces abundant pasturage. It is invaluable for short-ley sheep runs. (*b*) *English Wild White.* The true permanent form of white clover. The rapidity with which this variety forms a sward, thus excluding weeds, its beneficial influence on the quality of the grass growing in conjunction with it, and its excellent feeding value, combine to make it the most important clover for long leys and permanent grass. (See Wild White Clover.)

Trefoil—This is a useful plant because of its earliness, and is frequently used for sheep grazing. Cattle are not fond of it either green or in the form of hay, and on that account it should be used sparingly in seed mixtures.

Grasses—*Perennial Rye-Grass*—The majority of best pastures contain a high percentage of this grass, which will stand endless grazing, while under favourable conditions it produces a great weight of hay. It is essentially a grass for fertile soils, and on some poor soils it does not thrive, becoming dwarfed and wiry.

Italian Rye-Grass—Produces its maximum growth in its first harvest year. It produces very early growth in the spring, and also after the hay crop is taken. This early growth in the aftermath is of particular value in one-year hay crops where a second cut of hay is taken. For autumn and winter grazing it has no equal, frequently being sown with cereals in the spring at the rate of 28 lbs. per acre for grazing purposes after the corn is removed. Its habit of growth, however, is

SEEDS MIXTURES (*Continued*)—

detrimental to the best growth of clovers, and when sown in conjunction with these should be used sparingly.

Cocksfoot—Under proper management this grass is one of the most valuable for leys of two years' duration or longer. It is one of the earliest grasses to start growth in the spring and grows rapidly again after cutting or grazing. Under pasture conditions it must never be allowed to become tufted or old, or cattle will refuse it; it must be kept heavily grazed.

Danish stocks produce the earliest growth but are less leafy than the New Zealand and Swedish late-flowering stocks, which make better pasture plants.

Timothy—A late permanent grass which produces a heavy weight of excellent herbage but little aftermath. It thrives best on stiff soils and in districts of high rainfall. It is wise to include this variety in most mixtures for long ley or permanent grass.

Rough-Stalked Meadow Grass—This early permanent grass is more popular for long leys and permanent grass than it was a few years ago. It forms a beautiful, close sward in pasture which is relished by all stock, and in hay it has been shown to give a higher yield than was anticipated. Being shallow-rooted it is most suited to districts of medium or high rainfall, where it should find a place in most mixtures for long ley or permanent grass.

Crested Dogstail—This is a slow maturing grass, remaining fresh and green during the winter months, and is valuable for sheep pastures on poor soils. Owing to its wiry seed heads remaining uneaten by stock, it readily re-seeds itself, and is eventually apt to oust better species.

The following are the chief agricultural requirements which may be experienced, followed by a list of seed mixtures (see p. 1105) which are considered the most suitable in their respective localities today.

4-Year Leys and Permanent Grass—(*a*) Hay and grazing; where hay is of particular importance. (*b*) Hay and grazing; where grazing is of particular importance.

3-Year Ley—First year, mowing; second and third year, grazing.

2-Year Leys—(*a*) Hay both years. (*b*) Grazing both years. (*c*) First year, mowing; second year, grazing. (*d*) First year, grazing; second year, mowing.

1-Year Leys—(*a*) Hay, one cut. (*b*) Hay, two cuts. (*c*) Hay, one cut (early); aftermath for ploughing in for the potato crop. (*d*) Hay, one cut; aftermath for grazing. (*e*) Sheep grazing (early). (*f*) Sheep grazing (mid-season).

H. K. W.

SEEDS MIXTURES : CONTROVERSIES PAST, PRESENT, AND FUTURE —Historical Introduction—The gradual evolution of the type of seeds mixtures now largely employed in temperate countries is a matter of great interest.

From the evidence of the earlier writers it would seem that at first only clovers were employed; thus, Walter Blyth ("The English

SEEDS MIXTURES (*Continued*)—

SEEDS MIXTURES

Reference Number:	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Broad-leaved red clover	—	2	2	3	2	2	6	1	3	—	—	3	6	12	2	4	2	6
Late-flowering red clover	4	2	2	—	2	1½	4	1	2	4	5	3	4	—	2	—	2	—
Alsike clover	1	1	1	2	2	1	1	2	2	2	1	2	2	2	2	2	2	3
Dutch white clover (English)	—	—	—	—	—	—	—	3	2	2	—	—	—	—	4	4	4	7
Dutch white clover (New Zealand) ..	—	1	1	—	1	—	—	2	2	2	—	—	—	—	—	—	4	—
Wild white clover (English)	1	1	2	1½	1	¾	—	—	—	—	—	—	—	—	—	—	—	—
Trefoil	—	—	2	—	—	—	1	2	—	—	1	—	—	—	—	3	1	2
Perennial rye-grass	16	12	16	16	4	14	4	4	4	4	18	12	4	2	3	—	—	—
Italian rye-grass	—	3	3	4	2	—	2	3	2	2	—	3	3	3	3	4	2	—
Cocksfoot (Danish)	10	4	—	—	4	8	2	2	2	2	—	—	—	—	—	—	—	—
Cocksfoot (Swedish)	—	3	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—
Cocksfoot (New Zealand)	—	3	—	—	2	—	—	—	1	1	—	—	—	—	—	—	—	—
Timothy	4	4	4	—	1	4	2	2	2	2	—	—	—	—	—	—	—	—
Rough-stalked meadow grass	—	2	4	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Crested dogstail	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Pounds per acre	36	38	37	28½	24	31¼	22	22	23	22	25	23	19	19	16	17	17	18

NOTES.

Long Leys and Permanent Grass.

Ref.

1. Cockle Park mixture. Hay and grazing. Hay important.
2. Hay and grazing. Grazing important.
3. No cocksfoot. Grazing important.
4. No cocksfoot. Grazing (cheap mixture).
5. Yorkshire Wolds. Grazing and occasionally hay.

3-*Year Ley.*

Ref.

6. N.E. Scotland. First year hay, second and third grazing.

2-*Year Leys.*

7. Mowing both years.
8. Grazing both years.
9. First year mowing, second grazing.
10. First year grazing, second mowing.

1-*Year Leys.*

Ref.

11. Cockle Park mixture. Hay, one cut (late and inclined to lodge).
12. Hay, one cut.
13. Hay, two cuts.
14. Warpland. Hay, one cut; aftermath for ploughing in for the potato crop.
15. Hay, one cut; aftermath for grazing.
16. Sheep grazing (early).
17. Sheep grazing.
18. Yorkshire Wolds. Sheep grazing (1 lb. of rib grass per acre is usually added).

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

Improver Improved," 3rd edit., 1652) refers to the sowing of Flanders clover in this country, but says nothing about grasses. That mixtures consisting of clovers without grasses were employed to an appreciable extent, at least, up to 1778, is further shown by the fact that Coke of Holkham, when making sheep pasturage on light soils in Norfolk, relied solely upon clovers and herbs like ribgrass and burnet, although later he had recourse to grass as well as clover seeds.

The early use of "all clover" mixtures, which would certainly have included white clover, finds a parallel to-day in the mixtures which have been employed by Mr. Stanley M. Bligh in Breconshire—where on poor land he has successfully used simple mixtures strongly biased with clovers, and in one instance he actually and efficaciously seeded out a field with alsike and wild clover only (Stapledon and Davies, "Seeds Mixture Experiments in West and Central Wales," 1915-1925, *Univ. Coll. of Wales, Aberystwyth, Advisory Bull.*, No. 1, 1925).

There can be little doubt, however, as Middleton ("Formation of Permanent Pastures: The Selection of Seeds for laying down Land to Grass," *J. Board Agric.*, vol. xii., 1905) tells us, that perennial rye-grass had come to be used to an appreciable extent in mixtures as early as about 1677, and it would seem, moreover, that for some time this grass and clovers were the only "artificial grasses" employed, though it is more than probable that hay seeds from the lofts were sown with clover as soon as the use of rye-grass became at all general.

The so-called "natural grasses" had been studied and utilized in Sweden, and their introduction into this country was due to Benjamin Stillingfleet (1760) ("The Swedish Pan and Observations on Grasses," in Miscellaneous Tracts, 3rd edit., 1775), who, in order to procure seeds for trial, employed children to make collections (see also W. Miles, "On Grass Seeds," *J. Bath and West and Southern Counties Agric. Soc.*, vol. iv., 1856), and at about this time (1763), Sir Thomas Middleton further tells us, cocksfoot seed was obtained from Virginia, as also Timothy from the States. It follows that by the end of the eighteenth century seeds mixtures of considerable variety were being employed, and that grasses had begun to be studied from a practical point of view. This, the era of preliminary and rather haphazard, and in the main uninformed, exploration and trial may be said definitely to have terminated with the publication of Sinclair's "Hortus Gramineus Woburnensis," in 1824.

The whole question of seeds mixtures always has been, and still is, a controversial one. We first had the rye-grass controversy—and, although in rather different measure, we have it still. We next had the controversy centring around the mathematical basis of drawing up seeds mixtures. This was followed by the controversy as to the rival merits of simple and complex mixtures, and this in turn is likely to lead to a considerable difference of opinion as to the bearing of the utilization of the sward on the choice of a seeds mixture. Because it will assist us to arrive at a reasonable point of view, and because it will afford a convenient means of discussing a number of problems

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

relative to the whole question of seeds mixtures, we will devote this article to a brief consideration of these controversies.

The Rye-Grass Controversy—When perennial rye-grass was first employed in mixtures, the seed rate was excessive—frequently up to three bushels (over 60 lbs.) per acre. We have considerable evidence to show that many years elapsed before the commercial seed of rye-grass was anything approaching to reasonably clean; it is, indeed, inevitable that at first it must have contained great excess of Yorkshire fog and soft brome grass. We have evidence, moreover, which suggests that although it was recognized to a certain extent (for example, by Lawson, 1852) that perennial rye-grass was a variable, consisting of a number of different races and strains, the commercial seed in the main, and almost from the beginning, represented but a single and universal general type. The seed of commerce at a very early stage—unlike that of most of the natural grasses—would have been obtained from sown fields. In the light of what we now know about strains (R. G. Stapledon, "The Economic Significance of the Concepts, Nationality, Variety, and Strain as applied more particularly to Herbage Plants," *J. Nat. Inst. Agric. Bot.*, vol. i., 1924; *idem.*, "Cocksfoot Grass (*Dactylis glomerata* L.): Ecotypes in Relation to the Biotic Factor," *J. Ecology*, vol. xvi., 1928; T. J. Jenkin, "Perennial Rye-grass at Aberystwyth," *Welsh J. Agric.*, vol. vi., 1930; E. Bruce Levy and Wm. Davies, "Strain Investigation relative to Grasses and Clovers: I. Perennial Rye-grass," *New Zealand J. Agric.*, vol. xxxix., 1929; *idem.*, "Strain Investigation relative to Grasses and Clovers: II. Cocksfoot," *New Zealand J. Agric.*, vol. xxxix., 1929; *idem.*, "Perennial Rye-grass Strain Investigation: Data from Trials at the Plant Research Station," *New Zealand J. Agric.*, vol. xl., 1930; D. B. Johnston-Wallace, "Seeds Mixture Experiments in Yorkshire, Devon, and Essex, 1921-26," *Agric. Progress*, vol. iv., 1927; W. M. Findlay, "Report on Grass Seed Mixtures, 1907-13, with some Observations regarding more Recent Trials," *North of Scotland Coll. of Agric. Bull.*, No. 30, 1926; R. G. Stapledon and Wm. Davies, "Sensible Seeds Mixtures," *Welsh Plant Breeding Stat. Bull.*, Series H, No. 8, 1928; *idem.*, "Seeds Mixture Experiments, with Special Reference to the Influence of Environmental Factors," *Welsh Plant Breeding Stat. Bull.*, Series H, No. 8, 1928) and competition (Wm. Davies, "The Factor of Competition between One Species and Another in Seeds Mixtures," *Welsh Plant Breeding Stat. Bull.*, Series H, No. 8, 1928), but little imagination is required to picture the rapid evolution of the type of perennial rye-grass which has been responsible for the rye-grass controversy. The excessive seed rates would give the later strains very little chance in competition with the earlier, and this method of culture accompanied by taking seed crops in a first or second harvest year continued for but few generations would be enough very soon to stabilize commercial rye-grass as the product we know to-day—relatively early, relatively stemmy, relatively short-lived.

The rye-grass controversy has really turned on just this, that Fream

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

("The Herbage of Old Grasslands," *J.R.A.S.E.*, 2nd series, vol. xxiv., 1888; "The Herbage of Pastures," *J.R.A.S.E.*, 3rd series, vol. i., 1890), when he made his survey (by lifting turfs representing eighty different fields) of the pastures of the country, was recording the excellence of the indigenous strains, and the correctness of his estimate has subsequently been abundantly confirmed by Armstrong ("The Botanical and Chemical Composition of the Herbage of Pastures and Meadows," *J. Agric. Sci.*, vol. ii., 1907), Stapledon ("Permanent Grass," *Farm Crops*, vol. iii., 1925), Alun Roberts ("The Composition of Old Pastures of High Reputation in North Wales," *Welsh J. Agric.*, vol. iv., 1928), and others. Faunce-De Laune ("On laying down Land to Permanent Pasture," *J.R.A.S.E.*, 2nd series, vol. xviii., 1882), when he decried perennial rye-grass (with Yorkshire fog) as being "most pernicious to newly formed pastures," was in fact decrying the short-lived commercial strains and the land-fouling effect of excessive seed rates—bringing as these excessive rates did an abundance of seed of Yorkshire fog with them. Faunce-De Laune's interest in pasturage was as great as, or even greater than, his interest in hay, and Fream all along had insisted on the value of indigenous perennial rye-grass for pasturage. Thus Fream states, "it is in the pastures under the continuous treading and grazing of cattle that rye-grass is more especially qualified to luxuriate." The difference between "natural" and "sown" rye-grass was unfortunately not appreciated by Carruthers ("Observations and Experiments on some English Pastures," *J.R.A.S.E.*, 3rd series, vol. i., 1890), who subsequently not only championed the Faunce-De Laune thesis, but in general terms, and in no uncertain manner, committed himself to the view that perennial rye-grass as such was not a valuable pasture grass—this despite the evidence of Fream's survey and of a survey he conducted himself. (Writing of perennial rye-grass and criticizing Fream's finding relative to his survey—still the most complete published survey of the good pastures of this country—Carruthers affords us very quaint reading in the following utterance: "A reversion to the wild type is a misfortune and a loss. . . . A plant of Nature's sowing in the farm where it should not be is a weed to be eradicated"; while elsewhere he remarks that if more attention were directed to the whole rye-grass question it would "secure the complete elimination of rye-grass from permanent pasture in the future." A strange condemnation this, of what we know now to be one of our most valuable pasture grasses.)

Elliot ("The Agricultural Changes required by These Times and laying down Land to Grass," 1905), like Faunce-De Laune, was much influenced by the fact that Sinclair (*loc. cit.*) did not advocate heavy seedings of perennial rye-grass, but although objecting to rye-grass on its own account it must be remembered that Elliot was greatly impressed by the importance of deep-rooted grasses, and that the total exclusion of perennial rye-grass from his mixtures was largely due to the fact that he regarded it as a water extravagant plant.

A factor which undoubtedly contributed to an over-acceptance in certain quarters of the verdict of Faunce-De Laune, Carruthers, and

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

Elliot relative to the complete valuelessness of perennial rye-grass has been the fact that during most of the period between the laying down of Faunce-De Laune's first experiment and of Elliot's last experiment, New Zealand cocksfoot (cocksfoot being a species greatly favoured by Faunce-De Laune and Elliot) would, to a large extent, have been the cocksfoot seed of commerce—and thus relative to the commercial seed of perennial rye-grass, the commercial seed of cocksfoot (having regard to strain differences) would have stood at a greater advantage than is the case to-day.

Judged simply from the seeds mixture point of view, and in terms of the ordinary seed of commerce, a very strong case had undoubtedly been made out for the total exclusion of perennial rye-grass from long-duration mixtures, but it has been unfortunate that this had led to a general condemnation of perennial rye-grass as a pasture plant. For now that indigenous strains are on the market (*e.g.*, seed cleaned from wild white clover and that taken from really old pastures) and that pedigree strains are coming on the market, the "total exclusion of rye-grass" thesis becomes wholly untenable, and the modern farmer must side with Fream and accept perennial rye-grass (indigenous) as one of our most valuable pasture grasses—and the modern farmer can obtain clean seed.

In later years the rye-grass controversy has turned not so much on the acceptance or refusal of the value of perennial rye-grass as a herbage plant, as upon the correct seed rate to employ and relative to the rival merits of perennial and Italian rye-grass. Excessive seed rates, as explained above, are responsible for the introduction of large quantities of Yorkshire fog, and because this latter grass ripens its seed very quickly, Yorkshire fog spoliation is progressive from year to year, especially when hay is cut late; while it is again desirable to emphasize that excessive seed-rate favours the initial dominance of the early and short-lived strains (contributing to a general seed sample) and the consequent partial elimination of later and more persistent strains (which may have in some measure contributed to a general seed sample).

M'Alpine ("Report on Experiments on the Seeding of Pastures, 1901-4," *West of Scot. Agric. Coll. Bull.*, No. 31, 1905) conducted experiments which showed that for three-year leys seed rates of 20 lbs. and upwards of perennial rye-grass were excessive, and that Yorkshire fog spoliation was more or less proportionate to the excess of seed rate. Greig and Findlay ("Report on Grass Seed Mixture Experiments, 1906-9," *Aberdeen and North of Scotland Coll. of Agric. Bull.*, No. 15, 1909) followed with trials which showed that for leys 10 to 20 lbs. of perennial rye-grass was sufficient, and again that there was a close relationship between bent and fog spoliation and seed rate.

Exhaustive trials conducted by Findlay (*loc. cit.*) over a considerable period of years have confirmed the earlier results and definitely established the hampering effect of both the rye-grasses on the development of red clover, and on the slower establishing grasses.

Trials of a similar nature, supported by careful botanical analyses,

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

have been reported upon by Johnston-Wallace ("Experiments with Seeds Mixtures in the North Riding of Yorkshire, 1921-23," *Univ. Leeds Bull.*, No. 136, 1924); Alun Roberts ("Grass Seed Mixtures," *Univ. Coll. of N. Wales, Bangor, Leaflet*, 1925); Stapledon and Davies (*loc. cit.*); Davies (*loc. cit.*) and others; and leave no doubt as to the influence of the rye-grasses on other species sown in a mixture. The tangible result of all this work is that those who advocate comparatively simple mixtures usually include not more than about 14 lbs. of perennial rye-grass in their prescriptions, while those who adhere to more complex sowings reduce the perennial rye-grass to as little as 3 to 7 lbs.

The experiments above referred to have all been confirmatory in showing that perennial rye-grass in a mixture gives a heavier hay yield than Italian. On the whole, however, not sufficient emphasis has been laid on the greater leafiness of Italian than of perennial rye-grass, of its greater aftermathing ability and of its early spring growth —in short, on the relation of management and the character of the utilization adopted by the farmer to the potential usefulness of a grass species.

These effects have been insisted upon by Stapledon and Davies (*loc. cit.*), who, on the strength of extensive trials conducted at the Welsh Plant Breeding Station, advocate the inclusion of Italian rye-grass in mixtures when the swards will be grazed in the autumn of the seeding year, to some extent during the winter, and again in the spring, and in the case of all mixtures sown for pasturage only. The Craibstone experiments, however, have shown that even under autumn and spring grazing Italian rye-grass does tend to hamper the slower growing elements in the mixture; the Aberystwyth experiments as a matter of fact confirm this, but on the balance, and especially when the grazing will be excessive—and how often it is—we think the proper course is to include Italian rye-grass (about 4 lbs. per acre), a view which also appears to be held by Ross ("Seeds Mixture Trials," *Devon Agric. Cte. Scheme of Agric. Education and Guide to Exper.*, 1926) and others who have conducted more recent experiments. How important it is to particularize as to the bearing of management on the drawing up of seeds mixtures is shown by a statement made by Volkart ("The Principles of Compounding Mixtures of Grass and Clover Seeds," *Sci. Agric.*, vol. ix., 1929), who appears to have read Stapledon to the effect that he advocates the inclusion of Italian rye-grass in all mixtures. The truth is that Stapledon has always been at particular pains to make the reservation "when the leys will be grazed during the first autumn and spring after sowing."

The experiments we have referred to above have all been conducted with ordinary commercial perennial rye-grass, and in connection with leys from which hay has been taken in at least the first harvest year. None of these results can necessarily be taken to apply to pasture mixtures from which hay will never be taken, and which are designed to form leys or permanent pasture which will be scientific-

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

ally grazed from the very outset. When the perennial rye-grass used in such mixtures is an indigenous strain and is sown with perhaps but one other grass and with only one or at the most two clovers, trials in progress at Aberystwyth show that the seed rate should often exceed 14 lbs., and should on occasion probably even exceed 20 lbs.

The Mathematical Basis of drawing up Seeds Mixtures—When two workers who have deservedly attained to a great reputation investigating the same problem in different countries come to the same general conclusion and advocate the same general procedure, depend upon it the procedure so advocated, no matter whether sound or the reverse, will be largely followed. Such has been the case with the procedure first propounded by Stebler ("The Best Forage Crops," translated from the German by A. N. M'Alpine, 1889), and enthusiastically advocated by M'Alpine ("The Nature and Construction of Grass Mixtures," *Trans. High. and Agric. Soc. of Scot.*, 5th series, vol. i., 1889), with reference to drawing up seeds mixtures.

The plan was, first, to decide the proportionate area of ground that it was desirable should be covered by each species. This ideal mapping out would be settled by making a proper allocation between early and late species, top and bottom grasses, drought resisters and excessive moisture resisters, and the like. Thus, M'Alpine lays down the following rule for drawing up seeds mixtures: "To secure maximum produce the number of species represented in the mixture ought to be as large as possible. If one kind is affected by drought, another is ready to step in and take its place; if the land is too wet for one plant, another which revels in the moisture comes forward; if one is early, another is late, and so on . . . but we become almost independent of the seasons by blending suitable species." Secondly, on the basis of germination, purity, and number of seeds per pound, to calculate the correct seed rate for each contributing species.

In order that this method shall give the results expected it is necessary to assume (1) that soil establishment bears some very real and close relationship to laboratory germination, and (2) that the seeds having been sown they would establish plants in the proportions desired—in fact, that there was no such thing as competition between the several species. That the Stebler-M'Alpine thesis was utterly untenable was sufficiently proved by Sir Thomas Middleton (*loc. cit.*) on the basis of large-scale seeds mixture experiments, while more recently Stapledon, Davies, and Beddows ("Seeds Mixture Problems: Soil Germination, Seedling and Plant Establishment, with Particular Reference to the Effects of Environmental and Agronomic Factors.—I. Garden Trials," *Welsh Plant Breeding Station Bull.*, Series H, No. 6, 1927), and Davies ("Seeds Mixture Problems: Soil Germination, Seedling and Plant Establishment, with Particular Reference to the Effects of Environmental and Agronomic Factors.—II. Field Trials," *Welsh Plant Breeding Station Bull.*, Series H, No. 6, 1927), following up the early work of Lindhard ("En analytisk Undersøgelse af Plantedækket i en- og fleraarige Græsmarker 1877-1888," *Beretning fra*

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

Statens Forsøgsvirksomhed i Plantekultur, 31, 1908), have shown, as the result of critical small-scale trials, that the assumptions underlying this method of drawing up seeds mixtures could not for a moment be accepted. For example, the number of viable seeds in 1 lb. of commercial seed is one thing, but the probable number of established seedlings that will be given by such a pound of commercial seed is quite another thing, as the following figures (from Stapledon and Davies) show:

	Number of Viable Seed per Lb. (*in* 000's).	*Number of Established Seedlings per Lb.* (*in* 000's).
Perennial rye-grass ..	187	105
Cocksfoot	308	114
Timothy	1,070	321
Rough-stalked meadow-grass	1,775	248
Red clover	173	67

The results of the above noted investigations have also conclusively established that the effects of competition between species are very great, and that very slight differences in management have a profound influence on the trend of such competition.

Probably no informed person to-day accepts the Stebler-M'Alpine thesis as such, but the trouble is that it was for so long and so firmly established that innumerable type mixtures were drawn up in conformity with its assumptions, with the unfortunate result that such mixtures are still advocated in the pages of catalogues of eminently reputable, but equally " die-hard " seed firms. In this connection it is interesting to observe that Volkart (see Stebler and Volkart in the fourth edition of Stebler's "Die besten Futterpflanzen," 1913) does not enlarge upon the "ground covered" method of drawing up seeds mixtures, and indeed emphasizes the different reactions of early and late species, while in a later work Volkart (*loc. cit.*, 1929) expresses the definite opinion that it is unwise to include early and late species in one and the same mixture. Because the " ground covered " thesis of Stebler is no longer acceptable, it must not be supposed that Stebler and M'Alpine's classical work, "The Best Forage Crops," does not remain to-day an exceedingly valuable book, while Volkart's fourth edition with its numerous additions—and especially important are those dealing with " Sub-Species, Varieties, and Country of Origin " —despite the rapid advances made since 1913, is an invaluable work of reference to which all students of grass land should have access.

Complex and Simple Mixtures—The word " complex " has a relative meaning, for things that are complex when compared with each other may show an infinite degree of complexity, and so it is with seeds mixtures.

Thus when Faunce-De Laune was laying down land to grass, seeds mixtures advocated by the seed trade frequently contained as many as 23 species, while those of Elliot contained about 17 species. To-day Percival (" Seeds Mixtures for Permanent Grassland," *J. Min. Agric.*, vol. xxx., 1923) employs from 10 to 13 species in his complex mixtures.

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

A typical "Elliot mixture" is as follows: Cocksfoot 10 lb., tall oat-grass 3 lbs., golden oat-grass ½ lb., tall fescue 4 lbs., meadow fescue 5 lbs., hard fescue 1 lb., rough-stalked meadow-grass ½ lb., smooth-stalked meadow-grass 1 lb., Italian rye-grass 3 lbs., kidney vetch 2½ lbs., chicory 3 lbs., burnet 8 lbs., sheep's parsley 1 lb., yarrow ½ lb., late-flowering red clover 2 lbs., white clover 2 lbs., alsike clover 1 lb.; total 48 lbs. Percival gives the following mixture for medium soils: Perennial red clover 2 lbs., alsike clover 2 lbs., white (Dutch) clover 2 lbs., wild white clover ½ lb., perennial rye-grass 4 lbs., timothy 2 lbs., cocksfoot 2 lbs., meadow fescue 3 lbs., meadow foxtail 1½ lbs., rough-stalked meadow-grass ½ lb., smooth-stalked meadow-grass 1 lb., crested dogstail 1 lb., red fescue 1½ lbs.; total 23 lbs.

The difference of opinion that exists as to complex and simple mixtures largely results from an insufficient appreciation of the influences of management on the trend of competition between the species. In the case of mixtures for hay intended for fields which will be put up early and grazed but lightly in the autumn of the seeding year, inter-specific competition will be at a maximum, with the result that, let the mixture be never so well balanced, the later developing species and strains will be largely suppressed by the early developing. If, on the other hand, the field is carefully grazed during the early months and is put up to hay late and but a light crop taken, the competition between the late and early strains will be very greatly reduced, and under these circumstances it is feasible to include "earlies" and "lates" in one and the same mixture.

The mingling of "earlies" and "lates" is even more rational in the case of grazing-only mixtures, provided the grazing will be so conducted from the very outset that no one species or strain is permitted to smother or unduly hamper the others, and if necessary that the mowing machine will be brought to the help of the grazing animal. In proportion, therefore, as the mixtures tend in the direction of complexity, so must the management be complex.

The case for a complex mixture also presupposes considerable difference in the tastiness and feeding value of the different species of grasses compared one to the other, and similarly as between the different clovers. Since growth stage has such an overwhelming influence on nutritive value, and bearing in mind the evidence from the investigations of Fagan ("The Nutritive Value of Grasses, as Pasture, Hay, and Aftermath, as shown by their Chemical Composition," *Univ. Coll. of Wales, Aberystwyth, Advisory Bulletin*, No. 2, 1927) and his co-workers, it is very much to be doubted if the ordinary grasses do differ to a very appreciable extent in nutritive value—though they undoubtedly differ appreciably in palatability—although this latter property is again much influenced by growth stage. While unless a particular species or strain has some very marked and special nutritive value (*e.g.*, a high mineral content in respect of an important element that may be lacking in the sward as a whole), it is hard to see what use its presence can serve in but small amount on a sward.

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

The complex mixture represents an ideal, an ideal which no doubt on good land and under favourable conditions can sometimes be achieved, but it still remains to be asked whether, had the mixture been a little less complex, it might not have succeeded just as well. To-day there can be no doubt that the weight of scientific opinion is on the side of relatively simple mixtures, and definitely on the side of heavy seed rates for grasses like cocksfoot and timothy, and it is significant that in the main it is those workers who have conducted the most elaborate trials supported by the most laborious and accurate botanical analyses who stand the most solidly for the simple and relatively simple mixture.[*] But—and this is of the utmost significance as

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[*] Alun Roberts (*loc. cit.*), who has conducted long-continued experimnets in North Wales, finds, that by the fourth year in a pasture, the only sown species likely to survive are perennial rye-grass, cocksfoot, wild white clover, crested dogstail, and rough-stalked meadow-grass, and advocates mixtures including 9 to 10 species. Owing largely to the fact that it is customary to graze into the spring he includes Italian rye-grass in his mixtures, and he also includes broad red as well as late-flowering red clover, and he is a strong advocate of the inclusion of wild white clover " if only from the point of view of checking undesirable weeds." Alun Roberts and Jones ("Nationality and Strain Test of Grasses, with Observations on Pasture Analyses Methods," *Welsh J. Agric.*, vol. v., 1929) as a result of further experiments dealing with Dutch white and wild white clover state: " It demonstrates further that the sowing of Dutch white clover which is not permanent, in the hope that meantime wild white clover will of itself become sufficiently established to supplement and to replace it as it dies out, falls far short of what can be accomplished with an initial seeding of wild white clover." Findlay (1925), who has done an immense amount of critical work in Scotland, employs mixtures including 6 to 8 species for three-year leys and those including 11 to 14 for permanent pasture. Thus for permanent pastures Findlay's mixtures are as complex as Percival's, but they differ from those of Percival in that his sowings of perennial rye-grass go to 8 lbs.; of cocksfoot to 12 lbs., and of timothy to 4 lbs. Findlay, moreover, relies wholly on wild white clover, while Percival uses rather little wild white clover with rather much white Dutch clover. Johnston-Wallace (*loc. cit.*), who has had large experience in several counties, in the main advocates mixtures of Gilchrist's Cockle Park type with 6 to 8 species. Gilchrist's (" Seeds Mixtures and the Improvement of Grass Land," address delivered at the Plymouth Show of the Bath and West and Southern Counties Agric. Soc., 1922) original mixture consisted of 6 species (perennial rye-grass 14 lbs., cocksfoot 6 lbs., timothy 4 lbs., late-flowering red clover 4 lbs., trefoil 2 lbs., wild white clover ½ to 1 lb.). It is interesting to note that in his most recent paper Johnston-Wallace definitely advocates the addition of both Italian rye-grass and rough-stalked meadow-grass to the Cockle Park mixture, and that he puts the seeding of wild white clover at 1 lb. Ross (*loc. cit.*) follows the mixture of Johnston-Wallace, and adds Italian rye-grass to the Cockle Park mixture. He also includes alsike clover and white Dutch, as well as wild white, bringing his mixture up to 9 species and strains. Stapledon's (" Seeds Mixtures for Grassland," *J. Min. Agric.*, vol. xxx., 1923), and Stapledon and Davies's (*loc. cit.*), hay-then-pasture mixtures usually include 6 to 9 species and strains. The sowings of bottom grasses (rough-stalked meadow grass and/or crested dogstail) are heavier than usual, being from 3 to 4 lbs., while the wild white clover rate is seldom less than 1 lb. Italian rye-grass is generally included. The simple pasture-only (indigenous) mixtures consist of from 2 to 5 species, and always include large sowings of bottom grasses 3 to 4 lbs. and of wild white clover 3 to 4 lbs. (*e.g.*, Italian rye-grass 4 lbs., indigenous perennial rye-grass 20 lbs., rough-stalked meadow-grass 4 lbs., Montgomery red clover 4 lbs., wild white clover 3 lbs.). Messrs. Pattullo Higgs and Co., Ltd. (" An 'Old Pasture' Seeds Mixture," "*Phlo.*" *Monthly Circular*, vol. vii., 1928), make up mixtures of seeds taken from old Kentish pastures consisting of 7 species which differ only from the standard pasture mixtures of Stapledon in the addition of wild red clover, wild

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

bearing upon the controversy—it is the advocates of the simple mixture who more than any others are also the advocates of the inclusion of wild white clover in the mixtures. In addition to this, cocksfoot is invariably included in amounts of 6 lbs. and upwards, and timothy of 4 lbs. and upwards in simple mixtures, while in complex mixtures the amount of either of these grasses frequently does not exceed 3 lbs. It is also important to notice in the case of the very simple pasture mixtures consisting in many instances of no more than three or four species, as recommended by Stapledon (*loc. cit.*), that not only is great reliance placed on wild white clover, but equally on an indigenous strain of the chief contributing grass. In such mixtures perennial rye-grass (indigenous strain, of course) can rightly and usefully be made the dominant element in the sward, and can, and should, therefore, be sown heavily. If it is desired to make rye-grass a dominant element in the sward it is useless to sow a complex mixture, for the rye-grass, even an indigenous strain, will necessarily hamper the development of other grass species. The complex mixture, therefore, presupposes a sward with relatively little rye-grass in it and a seeds mixture in which the rye-grasses are excluded or only included in small amount, and such, indeed, are the Elliot and Percival mixtures.

The Bearing of Utilization on the Selection of a Seeds Mixture—The intention of this article has not been to give type mixtures for particular soil types, and indeed, in our view, soil type is by no means the first consideration in drawing up a mixture. Rather is it necessary to emphasize that it is of the first importance that mixtures should be drawn up in order strictly to conform with the utilization to which it is proposed to put both the juvenile and the adult sward. It would be an invidious and not wholly profitable task to attempt to criticize or appraise the value of mixtures advocated by the several competent authorities of to-day; and the more so since we are convinced that utilization has not received the attention it deserves at the

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bird's foot trefoil, and wild trefoil. Levy ("The Grasslands of New Zealand, Principles of Pasture Establishment," *New Zealand J. Agric.*, vol. xxvi., 1923), who has conducted very extensive investigations in New Zealand, employs mixtures of 4 to 9 ingredients for permanent pasture. Volkart (*loc. cit.*), who has carried out long-continued experiments in Switzerland, summing up the results of his experiments, remarks, "the results of these experiments are a warning against the use of too many species in a mixture." A great deal of work has been done on seeds mixtures in the Scandinavian countries, where, however, the mixtures used have always been simpler than in this country; thus Lindhard (1908) did not employ more than 7 to 10 species. The more recent work of Rhodin ("Försök med vallanläggning med flere eller färre växtarter. Meddelande N:o 204 från Centralanstalten för Försöksväsendet på Jordbruksområdet," *Jordbruksavdelningen N:o* 50, 1920), Osvald ("Några nyare synpunkter vid uppgörande af gräsfröblandningar för slåtter och betesvallar på torfjord, *Svenska Mosskulturföreningens Tidskrift*, 1920), and others in Sweden, and of Glærum ("Engforsøk paa oplændt jord," *Beretning om Statens Forsøksgaard paa Vold*, 1917) in Norway, is all in favour of mixtures considerably less complex than those of Lindhard, the results showing that it is possible to obtain high yields, winter hardiness, and permanency with mixtures composed of but 4 to 6 species.

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

hands of the student of grass land. Consequently we will conclude this article by an expression of personal opinion as to points demanding chief consideration with a view to drawing up seeds mixtures in a manner most likely to fit in with utilization. Owing to limitations of space we will only deal with mixtures for long duration leys and with sharply contrasting differences in utilization, although every shade of difference in management undoubtedly calls for a corresponding adjustment in seeds mixtures.

Hay every Year for the Duration of the Ley—The ley which has to cater for a heavy hay crop every year, and from which pasturage is a secondary consideration, presents the most difficult seeds mixture problem, for competition will be at its maximum.

For such mixtures it is therefore most rational to rely almost wholly on one of the larger and hay-producing grasses in conjunction with one or two leguminous plants, as instanced by the timothy meadows of Scotland, and the cocksfoot-lucerne leys employed to a limited extent in the South of England.

Ordinary commercial perennial rye-grass is not a suitable variety for such purposes, but it is probable that a good indigenous and long-lived strain would prove valuable for certain conditions. Pure stands of lucerne or sainfoin (old English) are of course invaluable as hay-producing leys.

Pasture Only—As already emphasized, the trend of competition can be controlled to a considerable degree in pasture-only leys, and consequently early and late species and strains can be made to contribute to one and the same mixture with very fair promise of success. The control, however, can be altogether more efficacious if the mixtures are drawn up so as to cater for seasonal productiveness by resort to special-purpose leys, each designed primarily to be of maximum usefulness at a particular period of the year. In this connexion it is necessary to emphasize that a pasture mixture designed for a field that will be grazed more or less continuously should be quite different from that designed for a field where the control will be intelligent and adequate. In the former case the mixture should be as simple as possible, and it would be idle to include both early and late species and strains. Simple pasture mixtures (with good excess of wild white clover and of bottom grasses and an appropriate indigenous strain of one of the larger grasses) will establish themselves satisfactorily with the minimum of soil preparation and go some way to justify Faunce-De Laune's assertion that it is the seeds employed that count for almost everything, and that the preparation of the land is not of prime importance.

Hay in the First Year (or in the Early Years) followed by Pasture—This is the scheme of utilization that the average long-duration seeds mixture has to cater for, and for which the Gilchrist (*loc. cit.*) Cockle Park type of mixture has proved so successful. A great deal, however, depends on whether the young ley will be grazed during the autumn of the seeding year, and upon the date of putting the field up to hay. If autumn grazing is adopted, as it so often is, and if

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

the fields are put up to hay late, as they so often are, and a really heavy hay crop is not allowed to develop, a strong case can be made out for the addition of Italian rye-grass to mixtures of this type, and for the addition of an adequate sowing of bottom grasses (which will not, under these conditions, be smothered out at the outset by the rye grasses). In this connection it is interesting to note that those who exclude the rye grasses or greatly reduce them in their mixtures have considerable resort to bottom grasses, thus Faunce-De Laune employed about 3½ lbs. of such grasses; and Percival's mixtures frequently contain 4 lbs. of bottom grasses, while even Elliot included them to an extent varying from 1 to 2½ lbs.

Hay and Pasture every Year—The advent of the late and persistent strain of the more important herbage grasses, together with a better knowledge both of the factors influencing the nutritive value of herbage, and the sustained productiveness of sward-forming plants, is likely to make for a new type of management which will in turn make new calls on the seeds mixture.

Kind of Seed.	*Weight per* 1,000.	*Kind of Seed.*	*Weight per* 1,000.
	Grams.		Grams.
Alsike	0·734	*P. trivialis*	0·143
Red clover (English)	1·773	Perennial rye-grass	2·004
Suckling clover	0·510	Italian rye-grass	2·134
White clover (wild)	0·557	Timothy	0·289
White clover (Dutch)	0·612		
Lucerne (English)	2·059	Barley, Plumage-Archer	46·429
Lucerne (Provence)	1·960	Barley, Spratt-Archer	46·150
Lupin (blue)	192·0	Oats, Abundance	39·705
Lupin (white)	276·0	Oats, Black Tartary	30·761
Lupin (yellow)	127·8	Oats, Victory	40·477
Sainfoin (milled)	15·232	Oats, Grey Winter	37·323
Sainfoin (unmilled)	23·684	Rye	27·825
Trefoil	1·620	Wheat, Little Joss	49·389
Birdsfoot trefoil	1·157	Wheat, Red Marvel	54·067
Trifolium, Early Red	3·412	Wheat, Yeoman	45·513
Trifolium, Late White	3·408	Beans, Field	568·123
Kidney vetch	2·272	Buckwheat	23·628
		Peas, Maple	206·749
Agrostis spp.	0·074	Peas, Dun	237·699
Aira flexuosa	0·409	Vetches or Tares	60·684
Cocksfoot	1·012		
Crested Dogstail	0·463	Cabbage	2·978
Chewing's fescue	0·794	Carrot	0·741
Fine-leaved sheep's fescue	0·300	Flax	6·784
Hard fescue	0·794	Kale, Marrow-Stem	3·752
Meadow fescue	1·854	Kale, Thousand Headed	3·551
Sheep's fescue	0·786	Kohl rabi	2·851
Tall fescue	1·877	Mangold	19·333
Meadow foxtail	0·768	Mustard	5·355
Golden oat-grass	0·239	Parsnip	4·528
Tall oat-grass	3·202	Rape	4·237
Poa compressa	0·154	Sugar-beet	23·126
P. nemoralis	0·199	Swede	2·829
P. pratensis	0·177	Turnip	2·080

(By courtesy of the Chief Officer, Official Seed Testing Station, Cambridge.)

SEEDS MIXTURES: CONTROVERSIES (*Continued*)—

The tendency will increase, we think, to use one and the same ley both as a pasture and as a meadow. Autumn and spring grazing will be heavy and the field put up to hay late, when a relatively light crop of highly nutritive hay will be taken from a great number of fields. The proper mixture for such utilization will be one combining early (for spring grazing) and late (for hay, autumn and winter grazing) varieties—but we think this will be catered for not so much by resort to a great number of species, but by blending different (early and late) strains of the comparatively few most suitable species. This type of mixture has been foreshadowed by some of the prescriptions suggested by Johnston-Wallace (*loc. cit.*), and by Stapledon and Davies (*loc. cit.*), while this method of utilizing leys and the question of the mixtures and the particular strains of herbage plants appropriate to such utilization is at present the subject of detailed investigation at the Welsh Plant Breeding Station. R. G. S.

SEEDS, WEIGHT OF COMMON AGRICULTURAL—The weight determinations given on p. 1117 were made by the Official Seed Testing Station, Cambridge, during recent months. The weight per 1,000 seeds in each case was obtained by weighing 2,000 to 5,000 seeds in lots of 100.

SEPARATORS AND CENTRIFUGES—In these instruments we employ what every schoolboy knows as "Centrifugal Force" to effect the separation of liquids of different specific gravities, or to induce the rapid sedimentation of suspended particles from a liquid.

Force is commonly defined as that which causes change of motion. If a planet moving freely in space is observed to change its motion in any way, not only in respect of velocity but also as regards direction, a force is assumed to act upon it, and the same thing holds on the earth's surface, except that the force in question may there be merely a frictional resistance. A ball rolled along a smooth road eventually comes to rest because it is continually acted on by a small frictional resistance, and a sky rocket ascends at an ever-increasing speed until the charge is exhausted, because it is helped by the constant recoil of the hot gases and sparks shot downwards. A force may act, however, in such a way as to change only the *direction* of motion, not its speed, as, for example, when a wind across the line of sight deflects a rifle bullet. Indeed, wherever the motion of a body is other than straight we find a force acting, and the particular force which keeps a uniformly moving body in a circular path is known as *centripetal force*, or, where it is for convenience regarded as being exercised by the body itself, as when a stone is tied to a string and swung round, as *centrifugal force*. The tension of the string in this case is constant if the stone is moving uniformly in the circle, and gives to the stone a constant acceleration at right angles to its line of motion, *i.e.*, towards the centre. And in all cases of circular motion the same is true —that is, there is a uniform acceleration of the particles *towards the*

SEPARATORS AND CENTRIFUGES (*Continued*)—

centre which is a measure of the magnitude of the force causing it—namely, the centripetal or, for convenience, centrifugal force. This force varies as the quantity $\frac{v^2}{r}$, where v is the velocity in the circumference and r the radius of the circle. The reason for this will be found in any elementary book on mechanics. The difficulty of understanding this arises from two causes: (i.) the speed does not increase, and (ii.) the body does not fall to the centre. As regards the first, it will be clear to anyone who drives a car that extra force is required to drive it when rounding a bend—unless the accelerator is depressed slightly it will lose way; and in regard to the second the answer is that the body *is* constantly falling towards the centre from its natural tangential path into the circular one it describes.

Now, according to the latest theories gravitation is nothing more or less than a force due to an acceleration, so that it is hardly to be wondered at that centrifugal force, which is equally a force due to an acceleration, can be used to perform for us any operation which can normally be performed by gravitation. Perhaps the real identity of these two may be rendered, if not more certain, at least more convincing by mentioning the experiment of Knight (see *Ostwalds Klassiker*, 62), who grew seeds on the circumference of a rapidly rotating wheel; the geotropic roots grew radially outwards, and negatively geotropic shoots radially to the centre.

The advantage of substituting centrifugal for gravitational force for many purposes arises from the fact that its magnitude is under control, and so processes which normally take hours can be performed in minutes.

Consider in Fig. 28 the globule of fat F suspended in the serum of the milk with which the beaker is imagined to be filled to the brim. If the mass of the fat globule is f, then its weight is fg, where g is the gravitational force; similarly if the mass of an equal volume of the serum is s, its weight is sg, and by the principle of Archimedes the force causing the globule to rise will be $sg - fg = g(s - f)$. Thus, if we can in any way increase g we can increase the force causing the globule to rise in like proportion, and this is, in point of fact, what we do when we substitute centrifugal for gravitational force. The same thing holds when a sediment is settling, but in this case the mass of particle of the sediment is greater than that of an equal volume of the liquid, and so on the balance there remains a force drawing the particle *downward* equal to $g(m - l)$, where m is

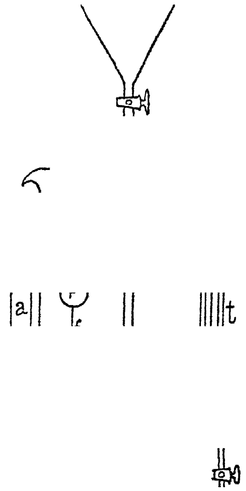

FIG. 28.—GRAVITATIONAL APPARATUS ILLUSTRATING THE PRINCIPLES OF THE SEPARATOR.

SEPARATORS AND CENTRIFUGES (*Continued*)—
the mass of the particle and *l* that of an equal volume of the liquid. As before, an increase in *g* will clearly cause a more rapid sedimentation.

There is, in the opinion of the writer, a distinct advantage in illustrating the principle of the cream separator by means of an imaginary apparatus designed to effect the same continuous separation under gravity alone. In Fig. 28 let the beaker be provided with a side tube *t* which reaches to within an inch of the bottom inside and turns down after passing through the glass, and ends in a stopcock below the level of the bottom. If now fresh milk is run in by the funnel shown and the flow is limited by the funnel stopcock to (say) 50 c.c. per hour, while the side tube stopcock is opened so as to allow (say) 45 c.c. per hour of milk from the bottom of the beaker to flow away by *t* when the milk has filled the beaker to the level of the bend of this tube, the beaker will gradually fill to the brim and 5 c.c. of cream will fall each hour from the beaker lip into the vessel *a*, while 45 c.c. of skim milk will pass by the side tube to the tumbler *b*, and as long as milk is fed in by the funnel the process will continue. Of course, in practice, owing to the time involved bacterial action would very quickly upset things, but the principle is exactly that on which a separator works, except that in the separator the value of the factor corresponding to *g* increases as we pass outward from the centre to the periphery of the bowl. Naturally since centrifugal force operates radially the milk will come to equilibrium round the periphery of the bowl of the separator with the cream at the centre, and the overflows for both cream and skim milk will have to be so disposed as to allow for a radial outflow. Similarly, the fresh milk will have to be fed into the part corresponding to the bottom of the beaker in Fig. 28—that is, to the periphery of the bowl—or at all events further from the centre than the maximum radial depth of the cream layer.

How the principle is operated in practice is illustrated in Fig. 29. Fresh milk is run in by the pipe indicated while the bowl is rotated at high speed. The skim milk is driven to the periphery and the fatty substances collect on the inside, forming a central cylinder of cream. Just as the skim milk flows away in Fig. 28 by an orifice the level of which is *lower* in the direction in which gravity acts, so in the separator it flows off by an orifice which may be regarded as *lower* in the direction in which the centrifugal force acts—that is to say, which is radially more distant from the axis. The cream and skim milk are received on circular trays as shown.

Space does not permit of a detailed description of the different forms of separators on the market. They differ not only in form, but to some extent also in principle. In many, for example, the bowl is of different shape from that shown in Fig. 29, and in many the bowl is filled with metal cones which are said to "break down the wall of the milk." The physical interpretation of this somewhat cryptic expression is that in passing rapidly to the centre the fat globules form a sort of sieve through which the milk serum and colloid particles have to pass; this passage is doubtless rendered easier when the

SEPARATORS AND CENTRIFUGES (*Continued*)—

metal cones provide solid surfaces on which the fat globules can roll and so allow the serum to pass by. The mode of collection of the milk and cream also varies enormously. A fairly full description of the different forms accompanied by no less than sixteen figures of different separators will be found in W. Fleischmann, "The Book of the Dairy," pp. 119-144 (Blackie, London, 1896).

The relative quantities taken off by the milk and cream orifices are regulated by a valve (not shown in Fig. 29), by which the size of the milk orifice may be altered at will and so more or less of the liquid be driven to find an outlet by the cream exit.

The rotation is imparted to the bowl by means of gearing from a power shaft or hand wheel, or in some cases directly from a small shunt wound or suitably compounded electric motor, or from a small engine or turbine provided with an efficient governor. A perfectly constant rate of rotation is of the greatest importance, any variation in speed causing a certain amount of remixing by eddying in the bowl. The bowl must for a similar reason be so mounted that it can rotate without rasping or quivering, which may be present due to imperfect manufacture, or to its shaft not being perfectly vertical.

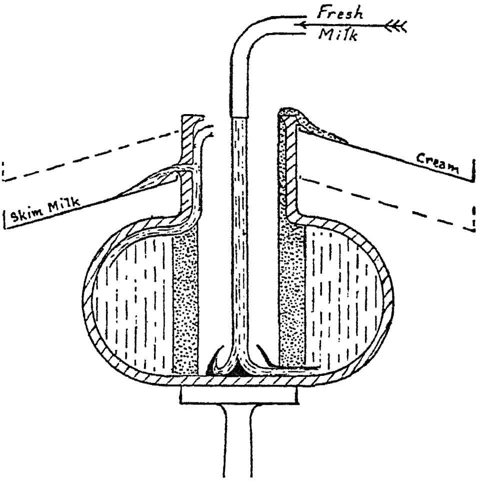

FIG. 29.—DIAGRAMMATIC SECTION OF A SEPARATOR BOWL.

The slime which covers the inside of the bowl after a separator has been working consists of parts of the milk of the nature of casein mingled with any solid impurities which may have been present in the fresh milk used, and a very considerable number of the bacteria originally inhabiting it. So that the process of separation effects some purification and the nitrogen loss is not serious.

The efficiency of separators is measured empirically by the percentage of fat left in the milk. This depends theoretically on the magnitude of the centrifugal force, the time for which it acts, and on the viscosity, which has a negative temperature coefficient. The first of these has been stated to be proportional to $\frac{v^2}{r}$, which may be written $\frac{(2\pi rn)^2}{r} = 4\pi^2n^2r$, in which for convenience in computation n, the number of revolutions per second, has been substituted for the peripheral velocity. The second factor—namely, the time for which the force acts—depends on the design of the bowl and the rate of flow of milk through it; while

SEPARATORS AND CENTRIFUGES (*Continued*)—

the third varies not only with temperature, but also with the special properties of the milk used. The formula

$$f = 1{\cdot}035^{\,40-t} \cdot \frac{km}{n^2},$$

built up in accordance with these principles, works well for some separators. f is the percentage of fat in the skim milk, t the temperature in Centigrade degrees, k a constant, and m the quantity of milk creamed per hour. Fleischmann found, however, that in many cases better results were obtained by using $\sqrt{m}$ instead of m in the formula, probably due to complications connected with the "wall of the milk" previously spoken of.

Centrifuges usually consist of a series of buckets of various forms hung from radial arms attached to a vertical shaft. They are so arranged that when the arms rotate the buckets can swing out into the same plane as that containing the arms. Into these buckets vessels can be inserted containing the liquids or suspensions to be separated, and the whole apparatus enclosed in a screen and rotated at a suitable speed, normally 3,000 revs. per min. for low-speed centrifuging and 10,000 revs. per min. for high-speed. What has been said as to the conditions of rotation in separators applies also to centrifuges, though slight variations of speed are of less account owing to the fact that the liquid is contained in the individual buckets. It is particularly important that proper radial balance be maintained in filling such apparatus. Failing this it is not unlikely, especially in high-speed working, that the whole apparatus may be wrecked, and the danger to life and limb is by no means slight.

Centrifuges are used in connection with agriculture in a variety of ways, as, for example, in securing rapid sedimentation of clay fractions in mechanical analysis of soils, in the extraction of oil from seeds by centrifuging the hot mash, in the deposition of waxes from cracked oils, and in milk analysis. T. D.

SESAME CAKE—For composition and feeding value see Feeding Stuffs.

SEWAGE SLUDGE—See Fertilizers.

SHEEP, Food Requirements of—See Foods and Feeding.

SHODDY—See Fertilizers, Miscellaneous.

SILICON (Symbol, Si; atomic weight, 28·06; atomic number, 14).—A brown-coloured element, crystalline or amorphous according to the mode of preparation. It does not occur native in the elementary state, but is of very wide distribution in combination, being an important constituent of all rocks, soils, and clays. (See Soil Colloids, Water-glass.) Silica (SiO_2) is present to a large extent in all soils. In the mineral silicate forms, in which it normally occurs in soils, it is insoluble in water, but the hydrated form of pure silica is soluble to a small extent in pure water and in water containing carbon dioxide in solution. Many natural waters contain a considerable amount, notably those

SILICON (*Continued*)—

of the geysers in Iceland, where masses of it are deposited round the rim, especially round that of the Great Geyser.

Some plants seem able to take up enormous amounts of silica, notably those of the genus *Equisetum*, and those of the tribe *Bambusæ* among the grasses. All plants and animals contain it to a small extent. Straws of cultivated cereals are comparatively rich in it, but it has apparently nothing to do with their standing power. It has been confidently asserted that traces of the silica gel exercise some sort of action, probably of a catalytic nature, considerably improving the harvest in cases of phosphorus deficiency (see Mazé, *Comptes Rendus Acad. Sc.*, clx., 211, 1915, and *Ann. Inst. Past.*, xxxiii., 147, 1919).

When all is said, however, its use remains problematical, since even those plants which absorb large amounts of it appear able to flourish quite well without it.

Animals contain less than plants, and excrete minute amounts in the urine. Cremer has recently used freshly precipitated colloidal silica as a "fæces marker" in metabolism experiments. In this connection it has obvious advantages over bones, where nitrogen, calcium, etc., are to be determined.

SISAL—Sisal, which is classed among the "hard fibres," is the fibre obtained from the leaves of certain amaryllidaceous plants of the tropical American genus Agave. *A. fourcroydes* Lemaire supplies the Mexican sisal, or henequen, which forms the bulk of the sisal of commerce, and is largely grown in Yucatan; *A. Cantala* Roxb. supplies the Philippine sisal, or maguey, while *A. sisalana* Perrine, a native of Central America, has spread widely through the tropics since the latter years of the nineteenth century, and is now grown in East Africa from Kenya to Natal, India and Ceylon, the Dutch East Indies, the Bahamas, and the West Indies. In the first of these areas it forms one of the major export crops.

The commercial expansion of sisal cultivation has proceeded with little critical scientific study of the plant. This is a typical xerophyte of slow growth with a life of from five to twenty-five years. At the end of the vegetative period the plant sends up an inflorescence or "pole," and dies. Reproduction is vegetative, by suckers arising from the base of the stem, or by "bulbils" developed from buds arising on the inflorescence in succession to the flowers which normally are shed without the formation of fruit. The main biological points which have a commercial bearing are three. The relative advantage of bulbils and suckers as a source of supply has been the subject of much discussion, but little critical investigation. It would appear that, as a single plant produces some 2,000 bulbils before death, the later may lack the vitality of those earlier produced, and, if only the earlier to mature were used, the supposed advantage of the sucker would be found to be non-existent. Of more importance is the length of life of the plant, for on the frequency with which replacement is necessary will depend the yield obtainable from a given area, since

SISAL (*Continued*)—

the plant occupies the ground for three years before cutting commences. Here again critical study is lacking, but it would appear that the conditions of growth which are necessary for the production of a commercial yield are not the natural conditions of a xerophytic plant like agave. The plant under the conditions of cultivation is forced, and hence tends to mature earlier. Whether it is possible to exert some physiological control over the plant at the critical period when it passes from the vegetative to the reproductive stage is a point worthy of investigation. The fact that plants of the same age in one plantation do not mature simultaneously, but over a period of years, seems to indicate that a slight environmental difference is the decisive factor and that it should be possible to find a solution to the problem. The third point of commercial interest where, as in the present case, competition has reduced the margin of profit, is the possibility of reducing costs by the use of the leaf waste, which, as the fibre constitutes only some 3½ per cent. of the total weight, is large. The most promising use of this waste is for the production of power alcohol by fermentation.

Information on the subject of sisal and allied fibres is to be found in "Sisal," compiled by H. Hamel Smith. H. M. L.

SLUGS—For description of nature of damage by and preventive treatment see Insect Pests of Cereals, under Wheat.

SMALL HOLDINGS, LAW RELATING TO—For the sake of brevity no reference is made hereunder to the rights and obligations of councils of county boroughs in connection with the acquisition of land for, and the provision of, small holdings. It must, however, be borne in mind that the powers and duties that have been conferred by the Legislature upon county councils in this respect are also applicable to councils of county boroughs with regard to their particular districts.

Powers and Duties of providing Land for Small Holdings—County councils were first authorized to provide, and assist in the provision of, land for small holdings by the Small Holdings Act, 1892. This Act, described as "an Act to facilitate the acquisition of small agricultural holdings," was passed for the purpose of checking a steady flow of population from the country into the towns, and of appeasing a discontent that had long been prevalent throughout the rural districts. Great results were not achieved under this Act; in fact, prior to the coming into operation of the Small Holdings and Allotments Act, 1907, some counties had failed to make any provision whatever for persons desirous of obtaining small holdings. This failure may be attributed to four reasons, namely:—

(1) Any county elector could petition his county council praying for the provision of small holdings, whereupon a committee of the council, on being satisfied that the petition was presented in good faith and on reasonable grounds, had to cause enquiry to be made as to the demand for the holdings as alleged in the petition and report thereon to the council, yet the decision to purchase land for the pro-

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

vision of small holdings in such county lay entirely in the discretion of the county council;

(2) A county council might not hire land on lease or otherwise for the purpose of letting it in small holdings except where the land required, through its proximity to a town or suitability for building purposes, or for other special reason, had a prospective value which, in the opinion of the county council, was too high to make its purchase for agricultural purposes desirable;

(3) Land could not be acquired for small holdings save at such price that, in the opinion of the council concerned, all expenses in respect thereof would be recouped out of the purchase money for the land sold by them, or in the case of land let, out of the rent. Moreover, proceedings might not be taken by a council under the Act which, in their opinion, would be likely to create a charge on the public rate exceeding one penny in the pound; and

(4) The Act did not confer compulsory powers upon county councils enabling them to acquire land in the event of no suitable land being available for acquisition by agreement, as a result whereof councils were unable to satisfy strong demands for small holdings which existed in many districts throughout the country.

The passing of the Small Holdings and Allotments Act, 1907, did much to facilitate the acquisition of land for small holdings by introducing Small Holdings Commissioners, extending the powers of county councils to acquire land on lease, and authorizing the compulsory acquisition of land for letting as small holdings. The Acts of 1892 and 1907 were repealed, and their provisions consolidated by the Small Holdings and Allotments Act, 1908. This latter Act remains operative at the present day, although many of the sections of the Act have been repealed and others have been amended.

An account of the duties of the Small Holdings Commissioners is now a matter of historical interest only, as these duties came to an end on the passing of the Small Holdings and Allotments Act, 1926, by repeals and amendments to the provisions relating to Small Holdings Commissioners contained in the principal Act of 1908. Small Holdings Commissioners were directed to be appointed to act under the directions of the Board of Agriculture and Fisheries, the functions of which Board were subsequently undertaken by the Minister of Agriculture and Fisheries. It was the duty of the Commissioners to ascertain the extent to which there was a demand for small holdings in the several counties, or would be, if suitable land were available, and the extent to which it was reasonably practicable to satisfy any such demand. The several reports of the Commissioners had to be submitted to the Board, together with a statement as to whether, in their opinion, it was desirable to formulate a scheme for the provision of small holdings and as to the nature of the proposals which ought to be embodied in such scheme. Where the Board, after considering the report of the Commissioners, were of opinion that it was desirable such scheme should be made, the report was forwarded to the county council concerned, who were under a duty to prepare and submit one

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

or more draft schemes within six months of receiving the Commissioners' report. Where the Commissioners had reported the advisability of formulating a scheme which would affect two or more counties, which report met with the approval of the Board, the scheme might be prepared by the councils jointly, and might provide for joint action being taken by them. In the event of the council or councils concerned failing to supply a draft scheme within the time specified or such extended time as might be allowed, the Board might direct the Commissioners to prepare a draft scheme. The scheme when prepared had to be considered by the Board, who might hold a public enquiry thereon, and were obliged to do so in the event of the county council objecting to the scheme or to any modification proposed by the Board to a scheme prepared by the county council. The Board, after considering the objections and the report of the person holding the enquiry (if any), might settle the scheme either unaltered or with such modifications as it might deem fit, or might annul the scheme. It was the duty of the county council or county councils concerned to carry out any such settled scheme within such time as therein specified, and, in the event of their failing to do so, the Board might authorize the Commissioners to carry the scheme into effect, in which case the county council was obliged to repay to the Board such expenses incurred by the Commissioners in so doing as should be certified by the Board. Any land thus acquired by the Commissioners became vested in the Board. Such land might be transferred by the Board to the county council at whose expense it was acquired, and had to be so transferred on payment of all sums due from the council in connection therewith and proof to the satisfaction of the Board that the council was willing to exercise and perform their powers and duties in relation thereto.

The principal Act of 1908 authorized county councils to hire land on lease for the purpose of providing small holdings for persons who desired to lease them, whether the land was within or without their respective counties. It also made provision for the compulsory acquisition of land for such purpose in the event of any county council being unable to acquire suitable land therefor by agreement and on reasonable terms. An order for the compulsory acquisition of land might be either for compulsory purchase, or for compulsory hiring for a period not less than fourteen nor more than thirty-five years, subject to renewal. No such order made by a county council could be enforced until it had been submitted to, and confirmed by, the Board of Agriculture and Fisheries. These provisions for the compulsory acquisition of land only applied when the land in question was required for letting as small holdings, so that in order that a county council might sell land for small holdings the land had to be acquired by agreement.

The Land Settlement (Facilities) Act, 1919, suspended the requirements as to the confirmation of orders for the compulsory acquisition of land, but prohibited county councils from acquiring any land for the purpose of small holdings without first obtaining the consent of

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—
the Board of Agriculture and Fisheries. These provisions of the Act, however, were only of a temporary character.

The Small Holdings and Allotments Act, 1926, as before mentioned, brought the duties of the Small Holdings Commissioners to an end, and county councils are now the sole judges as to the necessity for the provision of small holdings within their respective areas. By virtue of this Act, where a county council are satisfied that there is a demand for small holdings in their county by persons who desire to buy or lease and will themselves cultivate the holdings and are able to cultivate them properly, then it is the duty of the county council to make provision for such persons, whether the applicants be men or women, provided that the county council are of opinion that they can acquire land for the small holdings required without incurring loss. If it appears to a county council that a loss may be incurred in providing small holdings for such persons it is not lawful for the council to provide such holdings without first submitting their proposals to the Minister of Agriculture and Fisheries together with estimates of the expenses likely to be incurred by them in connection therewith and of the sums likely to be received either by way of rent, purchase money, or otherwise, and obtaining his approval to such proposals. The Minister, in giving his approval, may agree to contribute towards the losses likely to be incurred in carrying out such proposals out of moneys provided by Parliament, so, however, that the contributions in respect of any year shall not exceed 75 per cent. of the amount of loss shown in the approved estimates as likely to be incurred in that year.

A county council may not acquire land for small holdings, either by compulsion or by agreement, without first obtaining the consent thereto of the Minister, unless they are satisfied that the transaction will not involve any loss to the council; moreover, it is not lawful for the Minister to contribute to any loss that may have been incurred in the acquisition of land acquired without his consent. In acquiring land outside the county it is now necessary, under the Act of 1926, to consult with the council in which the land is situate.

The powers given to county councils, by the principal Act of 1908, for the compulsory acquisition of land for the purpose of letting small holdings, are extended by the Act of 1926 to enable them to purchase land by compulsion for the sale of small holdings. Orders made by a county council for the compulsory acquisition of land, whether by purchase or hiring on lease, are still unenforceable until confirmed, the Land Settlement (Facilities) Act, 1919, having dispensed with the necessity of obtaining such confirmation for a period of three years only. Orders are now submitted to the Minister of Agriculture and Fisheries for confirmation, the duties formerly performed by the Board of Agriculture and Fisheries having been taken over by him.

Provisions as to the compulsory acquisition of land by a council are contained in the First Schedule to the principal Act of 1908. Section 41 of that Act specifies certain restrictions to compulsory acquisition; these have been modified by the Land Settlement (Facilities) Act, 1919. No order may be made for the compulsory acquisition

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

of land which forms part of a garden or pleasure ground, or which is woodland not wholly surrounded by or adjacent to land acquired by a council under the Small Holdings Acts, or which is the property of any local authority or has been acquired by any corporation or company for the purposes of a railway, dock, canal, water, or other public undertaking, or is the site of an ancient monument or other object of archæological interest, or is land forming part of a park or of any home farm attached to and usually occupied with a mansion house, and is required for the amenity or convenience of the mansion house. No holding of fifty acres or less may be in whole or part compulsorily acquired where it is shown to the satisfaction of the council that the holding is the principal means of livelihood of the occupier thereof, except where the occupier is a tenant and consents to the acquisition: also, a council in making, and the Minister in confirming, an order for the compulsory acquisition of land must, so far as practicable, avoid taking an undue or inconvenient quantity of land from any one owner or tenant, and also avoid displacing any considerable number of agricultural labourers or others employed on or about the land.

Definition of " Small Holding "—The expression " small holding " means an agricultural holding which exceeds one acre and either does not exceed fifty acres or, if exceeding fifty acres, is at the date of sale or letting to the small holder of an annual value for the purposes of income tax not exceeding £100.

Section 20 of the Land Settlement (Facilities) Act, 1919, permitted a county council to provide a holding of less than one acre if it was not less than half an acre and had a cottage erected thereon, such holding being deemed to be a small holding although special provisions applied as to keeping of accounts in respect of such holdings. This section was repealed by the Small Holdings and Allotments Act, 1926, which introduced a new type of holding that can be under one acre known as a " cottage holding " (see below).

Powers in Relation to Land acquired for Small Holdings—If a county council are of opinion that it is necessary or expedient so to do for the better carrying of the Acts into effect, they may generally manage any land acquired by them for small holdings; also erect, repair, or improve any house or other building on the land, or execute any other improvement on or in connection with the land, or arrange with the tenant of any such land acquired by them for the execution of any such improvement on such terms as may be agreed; also sell, exchange, let, or mortgage any such land, subject, however, to the consent of the Minister of Agriculture and Fisheries where the land has been acquired with his consent, and, in the case of a mortgage, of such land, subject also to the consent of the Minister of Health. Also, in certain cases and subject to certain conditions, land held by a council for other purposes of the council may be appropriated for small holdings, and, conversely, land acquired for small holdings may be appropriated for other purposes of the council.

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

Regulations as to the Sale and Letting of Small Holdings—The power of a county council to let small holdings on lease was restricted by the Small Holdings Act, 1892, to holdings not exceeding fifteen acres, or an annual value, for the purposes of income tax, not exceeding £15, and even then if the land had been acquired by purchase such holdings could only be let on lease to persons who, in the opinion of the council, were unable to purchase them under the terms fixed by the Act. These restrictions were abolished by the Act of 1907.

Not only may small holdings be sold or let to persons who will themselves cultivate them and are capable of so doing, but one or more small holdings may be sold or let to a number of persons working on a co-operative system, provided such system is approved by the county council. Also, the Act of 1926 now permits the sale or letting of one or more small holdings, with the consent of the Minister of Agriculture and Fisheries, to any association formed for the purpose of creating or promoting the creation of small holdings, and so constitute that the division of profits amongst the members of the association is prohibited or restricted.

Small holdings purchased prior to the coming into operation of the Small Holdings and Allotments Act, 1926, are, in the majority of cases, still subject to a charge or other outstanding liability incurred in connection with their purchase under the regulations as to the mode of payment of purchase money for small holdings applicable at the date of sale. These regulations provide that on completion of the purchase the purchaser shall pay not less than one-fifth of the purchase money; a portion, not exceeding one-fourth of the purchase money, may, if the council think fit, be secured by a perpetual rent charge. The residue (if any) of the purchase money is to be secured by a charge on the holding in favour of the council, and shall either be paid by half-yearly instalments of principal with such interest, and within such term not exceeding fifty years, as may be agreed upon, or shall, if the purchaser so requires, be repaid with such interest and within such term as aforesaid by a terminable annuity payable by equal half-yearly instalments. The amount for the time being unpaid may at any time be discharged and such terminable annuity redeemed in accordance with tables fixed by the council; moreover, the council may agree to postpone payments of instalments for a term not exceeding five years in consideration of expenditure upon the holding by the purchaser.

The regulations as to the mode of payment of purchase money applicable to small holdings acquired at the present day are contained in Section 5 of the Small Holdings and Allotments Act, 1926. These provide that the consideration shall be a terminable annuity of an amount equal to the full fair rent of the holding, as determined by the council, for a period of sixty years, or, at the option of the purchaser, a terminable annuity for a period of less than sixty years of an equivalent capital value. Payments are to be made half-yearly, the first instalment payable on completion. As formerly, the council may agree to postpone payments of instalments (other than the —

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

instalment payable on completion) for a term not exceeding five years in consideration of expenditure upon the holding by the purchaser.

Conditions affecting Small Holdings Sold or Let—Every small holding sold by a council under the provisions of the Small Holdings Acts is held upon, and subject to, certain conditions as to user and disposal. Under the earlier Acts the conditions applied to a holding for a term of twenty years from the date of sale thereof, and thereafter so long as the purchase money remained unpaid, but small holdings sold under the Act of 1926 are held subject to such conditions for a term of forty years from the date of sale, and thereafter so long as the holding remains charged with a terminable annuity. The conditions now attaching to a small holding on purchase are very similar to those first laid down by the Small Holdings Act, 1892, and are contained in Section 6 of the Small Holdings and Allotments Act, 1926. They are as follows:—

(*a*) Any periodical payments due in respect of the terminable annuity shall be duly paid;

(*b*) The holding shall not be divided, sold, assigned, let, or sub-let without the consent of the county council;

(*c*) The holding shall be cultivated by the owner or occupier as the case may be, in accordance with the rules of good husbandry as defined in the Agricultural Holdings Act, 1923, and shall not be used for any purpose other than agriculture;

(*d*) Not more than one dwelling-house shall be erected on the holding unless, in the opinion of the council, additional accommodation is required for the proper cultivation of the holding;

(*e*) Any dwelling-house erected on the holding shall comply with such requirements as the county council may impose for securing healthiness and freedom from overcrowding;

(*f*) Any dwelling-house or other building erected on the holding shall be kept in repair and insured against fire by the owner to the satisfaction of the county council, and the receipts for premiums produced when required by them;

(*g*) No dwelling-house or building on the holding shall be used for the sale of intoxicating liquors;

(*h*) In the case of any holding on which, in the opinion of the county council, a dwelling-house ought not to be erected, no dwelling-house shall be erected upon the holding without the consent of the county council.

Small holdings let by a county council are held subject to the above conditions, except so far as these conditions relate to the terminable annuity and to repairs and to insurance against fire.

A county council may release or dispense with any of the above conditions, subject, however, to the consent of the Minister of Agriculture and Fisheries in respect of holdings of which a contribution is payable by him.

Powers of Recovery of Possession and Disposal of Small Holdings—In the event of a breach of any of the conditions affecting a small

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

holding, the council may, after giving the owner an opportunity of remedying the breach (if it is capable of remedy), either take possession of the holding or order the sale of the holding without taking possession; or, in the case of holdings let, after giving the tenant a like opportunity of remedying the breach, determine the tenancy. The council may also take possession of a holding, or order the sale thereof without taking possession, where the owner dies whilst the holding is so subject to conditions as aforesaid and the holding would by reason of such death become sub-divided, providing the council has given notice requiring the holding to be sold within twelve months after such decease and default has been made in selling it.

Sections 7 and 8 of the Small Holdings and Allotments Act, 1926, provide for the payment of compensation to an owner of a holding so taken possession of, or ordered to be sold, by a county council, in respect of his interest in the holding. It is also declared that the council may recover from the owner, as a civil debt, the amount of a deficiency, in the event of the value of the interest in the holding at the disposal of the council being less than the amount at which the annuity charged on the holding may be redeemed, together with any arrears of such annuity due from the owner.

Loans to Persons purchasing Small Holdings—In addition to the powers given to county councils to acquire land for small holdings under the Small Holdings Act, 1892, and the Small Holdings and Allotments Acts, 1908 to 1926, they have also been authorized by those Acts, should they deem fit, to assist in the purchase of small holdings coming within the description given in the Acts situate within or partly within their county, by making an advance to any tenant who has agreed with his landlord to purchase such an holding, such advance being made on the security of the holding. Before making any advance the council must be satisfied that the title to the holding is good, that the sale is made in good faith, and that the price is reasonable. Prior to the coming into operation of the Small Holdings and Allotments Act, 1926, the amount advanced could not exceed four-fifths of the purchase money, but by virtue of this Act the advance may now be made up to nine-tenths thereof. A small holding purchased with the assistance of a county council in the manner aforesaid is subject to the provisions of the Acts in force at the date of sale with respect to the purchase money or terminable annuity charged on the holding in respect of such advance as if the advance was the purchase money.

Powers to make Advances for the Equipment of Small Holdings—The Land Settlement (Facilities) Act, 1919, authorized the making of advances by way of loan for the purchase of livestock, fruit trees, seeds, fertilizers, and implements required for the purpose of a holding. This authority, however, has been withdrawn by the Small Holdings and Allotments Act, 1926.

By Section 14 of the Small Holdings and Allotments Act, 1926, a county council are empowered to advance money to owners of small

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

holdings provided by the council under the principal Act of 1908 as amended by that Act for the purpose of constructing, altering, or adapting, or undertaking to construct, alter, or adapt houses and farm buildings on such holdings and also to undertake to guarantee the repayment to a society incorporated under the Building Society Acts, 1874 to 1894, or the Industrial and Provident Societies Acts, 1893 to 1913, of any advance so made by the society to its members. Before granting any assistance under this section the council must satisfy themselves that when the work has been completed the house will be in all respects fit for human habitation, and the farm buildings will be in all respects suitable and necessary for the requirements of the small holding. No advance made under this section may be made until a valuation has been duly made on behalf of the council, and the advance must not exceed 90 per cent. of the value of the mortgagor in the property; instalments made during the carrying out of the work may not exceed 50 per cent. of the work done.

Delegation of Powers by a County Council—A county council may make arrangements with the council of any borough or urban or rural district in the county for the exercise by the council of that borough or district, within their district, as agents for the county council, of the powers of the county council in respect of the acquisition, management, and adaptation of small holdings. The county council may not, however, delegate their powers of submitting to the Minister of Agriculture and Fisheries proposals and estimates for the purpose of obtaining contributions (Small Holdings and Allotments Act, 1926, Section 9).

Small Holdings and Allotments Committees—Small holdings and allotments committees were first introduced in 1907. Every county council, other than the London County Council, is obliged to have such a committee consisting either wholly or partly of members of the council, but so that in any case the majority of the members shall be members of the council. All matters relating to the exercise and performance by a council of their powers and duties under the Small Holdings and Allotments Acts, except that of raising a rate or borrowing money, stand referred to this committee for their report, and, except in cases of urgency, no such powers may be exercised by the council until the report of this committee has been received by them. Councils may delegate any of their powers under these Acts to this Committee, except that of raising a rate or borrowing money, and such delegation may be subject to such restrictions or conditions as the council may think fit to impose.

A small holdings and allotments committee may delegate any of their powers to sub-committees consisting either wholly of members of the committee or partly of such members and partly of co-opted members, but power of appointing sub-committees does not apply to a small holdings and allotments committee of a council of a county borough.

SMALL HOLDINGS, LAW RELATING TO (*Continued*)—

Cottage Holdings—A cottage holding is much akin to a small holding, but differs therefrom in the limit of its area and the qualification of the persons by whom it may be acquired. This type of holding was introduced by Section 12 of the Small Holdings and Allotments Act, 1926, and cottage holdings are therein described as "holdings comprising a dwelling house together with not less than forty perches, and not more than three acres of agricultural land which can be cultivated by the occupier of the dwelling house and his family." All the provisions of the Small Holdings and Allotments Acts, 1908 to 1926, with respect to acquisition of land, provision and management of small holdings by county councils, other than those relating to the letting of holdings, apply to cottage holdings as if the expression "small holding" therein contained included cottage holding, but the power of providing cottage holdings is not exercisable by the council of a county borough, and a county council may not sell a cottage holding unless they are satisfied that the person to whom it is to be sold is a *bonâ fide* agricultural labourer or a person employed in a rural industry within or adjacent to their county, and that he has the intention, knowledge, and capital to cultivate satisfactorily the land forming part of the cottage holding. J. D. M.

SMUT, in Cereals (*Tilletia* spp.; *Ustilago* spp.)—See Diseases of Cereals, under Wheat; Seed, Transmission of Diseases by.

SNOW is formed by the direct condensation of water vapour to the solid state in the air. The fine dust motes act as nuclei upon which this condensation can proceed, and it is owing to the complete freedom of movement enjoyed by the minute crystals in their development that the perfect symmetry of snow crystals depends. The best and rarest forms occur for some reason always in the anterior quadrants of storms or between two contiguous storms. (For numerous illustrations and further information see article Snow in *Enc. Brit.*, 14th edit.)

It is commonly stated that snow serves to keep the ground warm in winter, and this is true with reservations. It cannot keep the *surface* of the ground *above* freezing point, but it may hinder radiation from the surface and so keep it at freezing point, *i.e.*, prevent its sinking lower than this. How far this occurs will depend, of course, on the external and subterranean temperatures; by enclosing a layer of still air it acts as a heat insulator much like a blanket on a bed.

SODIUM AND ITS COMPOUNDS—Sodium (symbol, Na; atomic weight, 22·997; atomic number, 11) is a soft silver-white metal of specific gravity 0·9712; it is used in the manufacture of indigo, and many other commercial processes, and is produced nowadays in large quantities by the electrolysis of fused caustic soda or salt. From the agriculturist's point of view, however, it is the sodium ion and the compounds of sodium which are of chief interest.

Sodium Ions—While almost all actions of sodium compounds may eventually be traced to the ions, there is one effect which must be

SODIUM AND ITS COMPOUNDS (*Continued*)—

dealt with definitely under this head—namely, the action of sodium ions in the blood of animals. These ions are responsible for the maintenance of the excitability of muscles in the body, but their action on heart muscle shows that this may also be affected by other factors. In the case of the heart apparently the presence of calcium and potassium ions is also necessary if the beat is to be maintained, since in pure isotonic sodium chloride solution an excised heart gradually ceases to beat; while the introduction of calcium enables the beat to continue for a long period. Even then, however, arrest in systole soon intervenes if a trace of potassium is not present. The action is doubtless on the cell membrane, $Na^{\cdot}$ increasing and $Ca^{\cdot}$ decreasing its permeability. For land plants sodium is apparently unnecessary, but it is of distinct use to halophytes, which leads one to conclude that a *close* grouping of these with xerophytes requires more careful consideration. (See S. Kostytschew, "Pflanzen Physiologie," Berlin, p. 283, 1926.)

Sodium Acetate ($NaC_2H_3O, 3H_2O$) is used to some extent in the preservation of meat and in the preparation of mordants. The *arsenate* (Na_3AsO_4) and *arsenite* (Na_3AsO_3) are used as insecticides. (See Insecticides and Fungicides.)

Sodium Bicarbonate ($NaHCO_3$) is present in the blood of animals, where it has an important buffer-action (see Acids); apart from this it is used in the tanning and baking trades, and largely in medicine. It is the chief immediate product of the ammonia-soda process, in which carbon dioxide is forced under pressure into ammoniacal brine.

Sodium Bisulphate ($NaHSO_4$), a by-product in the manufacture of nitric acid, is employed in the manufacture of ammonium sulphate. The solution is treated with ammonia gas while hot, and the following reaction ensues:

$$2NaHSO_4+2NH_3=Na_2SO_4+(NH_4)_2SO_4,$$

the normal sulphate crystallizes out, and the ammonium sulphate remains in the mother liquors, from which it may be obtained for use as a fertilizer.

Sodium Bromide ($NaBr$) is used as a nerve sedative. (For the *borate* see Borax.) The *benzoate* ($NaCO_2.C_6H_5$) is used as a food preservative and in medicine.

Sodium Carbonate (washing soda, $Na_2CO_3.10H_2O$) occurs naturally in British Columbia, but is usually made nowadays by calcining the bicarbonate obtained in the ammonia soda process (see above). It was previously got by the Leblanc process, for which see any textbook of inorganic chemistry. It has important detergent and cleansing properties, and a solution of it may be used as an aid in removing rust from ironwork preparatory to repainting. Sodium carbonate is the most vicious of the three principal salts affecting alkaline soils, the other two being the chloride and sulphate. It is in these cases called *black-alkali*, because, having a solvent action on the humus and a puddling action on the soil generally, it betrays its presence by charac-

SODIUM AND ITS COMPOUNDS (*Continued*)—

teristic black patches. These alkalies are products of the natural weathering processes in arid regions, and the problem is intensified by the fact that irrigation, made necessary by the climatic conditions, only augments the trouble. Sodium carbonate is the factor responsible for the direct injury to the crown of the plant, which takes place in these soils. (For a full account of this and methods of reclamation see Hilgard, "Soils," pp. 422-484.)

Sodium Chloride ($NaCl$) is common salt. A crystalline salt found native in large quantities in this and other countries, and the chief saline constituent of sea-water. It is used for preserving meat and hides, in the latter case usually in the crude form as rock-salt, in which state also it is used by wild animals in some parts of the world, where small outcrops of it are known as "salt licks." To the well-being of the animal organism it is quite necessary, as it is largely by it that the blood serum is kept up to the proper osmotic pressure. Salt and other useful materials passing out in the glomerular filtrate of the kidney are largely reabsorbed into the system by the walls of the renal tubules. When the flow of urine is large, these walls have only a short time in which to act, and sodium is consequently removed from the system, and when this process is prolonged the effects may be serious, due to the draft on the skeleton for sodium involving the solution and excretion of calcium, phosphorus, etc., and resulting in a rachitic state. Hence fodders in which the ratio of sodium to potassium is very low should be avoided to prevent sodium loss in the excretion of potassium.

Sodium Chlorate ($NaClO_3$)—A solution of this salt is secreted by the lachrymal gland. The *citrate* is used in medicine. (For the *carbolate* see Phenate.)

Sodium Cyanide ($NaCN$) is used preferably to potassium cyanide with sulphuric acid for generating hydrocyanic acid gas (*q.v.*). (For the *fluoride* and *silicofluoride* see Insecticides and Fungicides.) The *glycero-phosphate* is used in medicine.

Sodium Hydroxide ($NaOH$, caustic soda)—a white, very hygroscopic solid—is used in soap-making for the decomposition of fats, and is now made almost exclusively by the Castner-Kellner and other electrolytic processes. Mixed with quicklime (soda-lime), or alone, it is employed for drying gases and as an absorbent for CO_2 in the laboratory, as well as being used as a powerful reagent in a large variety of reactions, for further particulars of which see any textbook of agricultural or general organic chemistry.

Sodium Hydrosulphite ($Na_2S_2O_4$) is one of the most powerful reducing agents known; it is used in sugar refining, for removing iron compounds from soap, and in calico printing. The *hypochlorite* in solution is known as "bleaching solution," and liberates chlorine in the presence of acids; it is the active principle of the disinfectant "Milton." The *manganate* and *permanganate* are used in the tanning and bleaching industries; a solution of the latter is sold as "Condy's Fluid."

Sodium Nitrate (caliche, Chili saltpetre, $NaNO_3$) is a crystalline salt, found native, and used for curing meat, and as a fertilizer (*q.v.*), also in

SODIUM AND ITS COMPOUNDS (*Continued*)—

the manufacture of nitric acid and explosives and in pyrotechny. The *nitrite* ($NaNO_2$) is also used in meat preserving. The *nitroprusside*, ($Na_2Fe(NO)(CN)_5$) is used as a reagent giving a violet colour with sulphides. The *oxalate* occurs in varec (see Kelp), and is used in tanning.

The various *phosphates* of sodium are of importance in the baking trade, and in the blood they provide one of the chief buffer agents. (See Acids.) The *hypophosphite* is used in medicine. The *phenate* (C_6H_5ONa) is used as an antiseptic.

Sodium Sulphate (Glauber's salt, $Na_2SO_4 10H_2O$) is a valuable purgative. The *sulphites* are used in brewing and for the production of SO_2 in bleaching. The *sulphide* is used as a depilatory in tanning, and in the artificial silk, dyeing, and paper-making trades. (For *sodium silicate* see Water-Glass.)

Sodium Tartrate ($Na_2C_4H_4O_6 . 2H_2O$) is used in medicine, and the *tannate* for removing boiler incrustations.

SOILS, Origins and Constitution—Soil consists of mineral matter, organic matter, soil solution, and soil air. The mineral matter originates from the weathering and decay of rocks, and includes particles of varying sizes—namely, stones, gravel, sand, silt, and "clay." In this connexion the term "clay" is used to denote the finest particles of the soil, and is sometimes defined as that portion of the soil consisting of particles less than 0·002 millimetre (0·00008 inch) in diameter. In heavy soils, the finer particles predominate, whilst in light soils there is a preponderance of the coarser grades. The "clay" fraction originates from the chemical decomposition of rock silicates, and is essentially a mixture of hydrated silicates of aluminium and iron. The remainder of the mineral matter, including the coarser material, forms a kind of framework or skeleton of relatively inert material, and consists of fragments of parent rock and constituent minerals. Particles of calcium carbonate may form an important and even dominant constituent in chalk soils.

Organic matter originates from the decay of the remains of vegetation. The vegetation of uncultivated soils, the ancestors of farm soils, year by year contributes organic matter to the soil in leaf fall or in the residues of herbaceous and graminaceous plants. These are acted upon by bacteria, fungi, and other organisms. Two types of decomposition may be distinguished. With good aeration and an adequate supply of lime, the decomposition is mainly a destructive oxidation to carbon dioxide and water, and increases in intensity with rise in temperature, provided sufficient water be present. The continued prevalence of such conditions prevents the accumulation of organic matter in the soil. Under other conditions, plant residues undergo a process known as humification and accumulate as a dark-coloured structureless material called "humus," which forms about 80 per cent. of the soil organic matter. Humification occurs to some extent in all soils, but is the dominant process when aeration is defective, as in waterlogged soils, where the tendency is towards

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peat formation. Good examples of peat bogs are found in Wales, Scotland, and, above all, in Ireland, where the great Bog of Allen occurs in a basin-shaped area in which natural drainage is impossible on account of lack of adequate fall to the sea. (See Peat.) Humification also occurs where bases, principally lime, are very deficient, as, for example, in heath soils; and it occurs where drought stops biological decomposition, as in the black-earths of Russia and America. The amount of organic matter in ordinary British soils varies from 2 per cent. to about 10 per cent., and reflects the relative prevalence of the oxidative and the humifying processes as well as the rate of addition of plant residues and, in cultivated soils, of organic manures. The lowest amounts are found in sandy and chalky arable soils of south-east England and the highest in pasture soils of the west of England, Wales, west of Scotland, and Ireland. Earthworms play an important part in the decomposition of plant residues in the soil, principally by facilitating their distribution throughout the soil layers.

Clay and organic matter together form the colloidal complex. This complex behaves as a mixture of weak insoluble acids, more or less neutralized by bases, principally calcium, with smaller amounts of magnesium, sodium, and potassium. It governs the chemical and physical properties of the soil, and is the medium in which soil organisms fulfil their functions. The soil solution is intimately associated with the colloidal complex of the soil. Its composition varies considerably, but the principal cations are calcium, magnesium, and in smaller concentrations, potassium and sodium; the principal anions are bicarbonate, sulphate, and chloride, with varying proportions of nitrate, and traces of silicate and phosphate. The composition of drainage waters is similar to that of the soil solution. The roots of plants absorb certain essential constituents from the soil solution. Soil air resembles atmospheric air in composition, but is much richer in carbon dioxide, and is usually saturated with water vapour.

Soil is not merely a mixture of mineral particles and organic matter. It has a definite structure, rendered possible by the presence of the clay-humus colloid, which cements the soil particles together into compound particles or crumbs. The crumb structure is developed in soils under a good tilth. It is favoured by the action of frost, by alternate wetting and drying, by judicious cultivation, and by the presence or addition of calcium carbonate or lime. Where the crumb structure is destroyed, as by trampling under wet conditions or bad cultivation, the soil lies compact and impervious to water and air. In other words, the soil becomes poached or puddled. One principal difference between soil and subsoil is the greater development of the crumb structure in the former. The aim of cultivation should be the maintenance of the crumb structure.

Soil in Relation to Plant Growth—The object of cultivation and manuring is to ensure the best possible conditions for plant growth, and it is therefore important to know what factors are concerned therein. Plants are composed of water, organic matter, and ash

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constituents. Water is, of course, obtained by plant roots from the soil moisture, the supply of which, though ultimately governed by rainfall, is affected by soil conditions and, to some extent, controllable by cultivation and management. The organic matter of plants, consisting principally of carbohydrates, fibres, fats, and proteins, contains as its characteristic element carbon, obtained by the plant from the carbon dioxide which forms about 0·03 per cent. of the atmosphere. Green plants, using light as a source of energy, utilize carbon dioxide, building up the carbon into organic matter and liberating oxygen. In this process, the cultivator can scarcely hope to intervene, for light and carbon dioxide are not, under field conditions, within his control. He does, however, combat weeds with smothering crops which act by excluding the light from the soil. Plants, like other organisms, require oxygen for respiration. This condition applies to germinating seeds and to the roots of plants. An adequate supply of air in the soil is thus essential for germination and growth, and is an object of intelligent cultivation.

Whilst water and carbon dioxide are obtained from atmospheric sources, the other constituents must be obtained from the soil. The elements thus obtained by plant roots are nitrogen, phosphorus, sulphur, calcium, potassium, magnesium, and a few others which, if essential, are only required in small amounts. Ordinary soils contain abundance of these elements, with the possible exceptions of nitrogen, potassium, phosphorus, and calcium, and in these cases deficiencies must be remedied by manuring. We may refer to this group of growth factors as plant food.

Growth is affected by temperature. For agricultural crops little or no growth is possible below 42° F. The most favourable temperature for growth varies for different crops, but the optima for most British crops lie within the range of temperatures experienced during ordinary growing seasons. We shall discuss soil temperature at a later point in this account.

Absence of injurious substances forms another group of factors in plant growth. Amongst injurious substances may be mentioned acids, poisonous metallic compounds, and sodium salts in excessive concentration. Other factors affecting plant growth are root hold, absence of excessive competition, and freedom from insect, fungoid, and other pests.

We have seen from the foregoing outline that plant growth is governed by a number of factors, all of which must operate favourably for satisfactory crops to be obtained. We may liken fertility to a chain whose strength is that of its weakest link. If all the factors operate favourably with one exception, then the exception becomes the limiting factor which must be improved before good crops can be obtained. The task of the agricultural scientist is to discover what is the limiting factor in each case.

Physical Properties of Soils—Having considered in outline the demands of the plant on its environment, we may now view the prin-

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cipal properties of the soil in order to understand in what respect soils may be unsatisfactory and how they may be improved. We shall discuss the properties which affect soil moisture, soil air, tillage, and soil temperature.

It is obvious that, in a given volume of soil, a proportion is occupied by interstitial spaces. The proportion of space in 100 volumes of soil is known as the pore space. The pore space varies from about 50 per cent. in pasture soils down to 30 per cent. or less, in the case of compacted arable soils. It is increased by cultivation and decreases from soil to subsoil. Pore space represents the maximum air and the maximum water capacity of a soil. When about half of the pore space is occupied by water we have approximately optimum conditions.

The fertility of a soil is largely dependent on its ability to supply sufficient moisture to plants without, at the same time, being saturated with water to the exclusion of air. The soil must thus provide for drought and for excessive rainfall. Its behaviour during drought will depend upon its ability to retain sufficient available moisture from one rainfall to the next. In this connexion, situation is of importance, for it governs to a great extent the position of the water table, *i.e.*, the level at which the soil or subsoil is completely saturated with water. The water table follows in a general way the surface contours, but is nearer the surface in valleys than in uplands. In permanently waterlogged soil, the water table is practically at the surface. The water table is naturally lower in summer than in winter. Its position is affected also by the nature of the underlying strata. Clay strata impede downward movement and retain water. Obviously, a soil with the water table at a few feet from the surface is less likely to suffer from drought than a soil with the water table at 50 or 100 feet. But even with the same position of the water table soils differ in their ability to retain water after rain. Briefly, organic matter and clay are the effective constituents in determining water-holding capacity. Soils rich in either or both of these constituents have high retentive power, whilst open sandy or chalky soils poor in organic matter have low retentive power, and can only grow satisfactory crops if the water table is fairly near the surface. For example, certain very coarse sands in Anglesey carry fair crops, notably carrots, owing to the presence of water at 2 or 3 feet. The same kind of soil at higher levels is barren dune.

It cannot be assumed that the whole of the water present in a soil is available for the use of plants. A soil may be dry to all appearances, and still retain a few per cent. of moisture, known as hygroscopic moisture. Obviously this moisture is unavailable. It has been found that the water content at which a soil is just able to supply water to plants is closely related to the amount of water it can hold by hygroscopicity. This unavailable moisture is greatest in clay and organic soils and least in sandy soils. A heavy soil with 10 per cent. of moisture may have no water available for plant growth, whilst a sandy soil with the same amount may have several per cent. available.

SOILS (*Continued*)—

The supply of moisture to crops during drought is mainly drawn from the moisture stored up in the soil within the root range of the crop. Root development, fostered by drainage and deep tillage, is thus an important factor in drought resistance. To some extent moisture supply during drought is supplemented by capillary rise from the moister strata below the root range, or from the water table. Capillary rise acts through great depths in clay soils, but may be so slow as to be of negligible importance. In sandy soils, capillary rise is more rapid, but only effective through small depths. Loam soils are most satisfactory in this respect.

Whilst water is essential in plant growth, an excess of moisture in the soil implies a deficiency of air, which is equally important for plant growth. A fertile soil must supply sufficient water to crops, but must also readily suffer any excess of water to drain away. Thousands of acres of otherwise fertile land are unsatisfactory because, either owing to a high water table or to their impervious character, they do not permit excessive moisture to drain away, and are thus waterlogged.

A general deficiency in moisture is met by irrigation, a practice which is rarely encountered in this country, except in sewage farms and in water meadows. Yet it is certain that in an average season there are periods of deficient rain when a supply of water might increase or even save a crop. Though generally impracticable, it might be possible in some cases to devise cheap systems of irrigation. Sandy soils are most liable to suffer from drought, and every effort should be made to increase their water-holding capacity by addition of organic matter, by dressings of farmyard manure, by green manuring (*q.v.*), and by means of grass leys.

Excessive moisture is removed by drainage (see Draining), which consists essentially in lowering the water table. The benefits are manifold, but consist chiefly in improved aeration, which renders possible a deeper root range, and, indirectly, greater resistance to drought. The soil, being drier, is more easily worked and warms up more readily under the sun's rays. The removal of superfluous water is facilitated by cultivation and management designed to promote open tilth. Compact soils will be wet, although the water table may be lowered by drainage. The improvement in the texture of clay soils consequent on liming may facilitate drainage.

Ordinary arable cultivations all affect moisture conditions. Autumn ploughing leaves the soil in a rough state, so that it absorbs rainfall and lies open to the pulverizing effect of frost and thaw. Spring ploughing and harrowing produces a mulch of dry soil, and protects from losses by evaporation. Rolling after sowing compacts the soil, and by establishing capillary connexion with the moist subsoil, brings the moisture to the germinating seeds. Intertillage of root crops, besides destroying weeds, aerates the soil and establishes a moisture-saving mulch.

The working properties of soils are affected by their moisture content. Clay soils are plastic when certain proportions of moisture are present, and cultivation under such circumstances will only "paste" the soil

SOILS (*Continued*)—

and destroy its tilth. The point where a soil is just dry enough to be no longer plastic is the highest moisture content at which it can be worked. On the other hand, a heavy clay soil, when too dry, sets into clods which cannot be broken down until moistened again by showers. Such soils can only be cultivated when they are in the right condition. Winter frost assists greatly in the granulation of heavy soils—witness the good tilths obtained after the frosts of 1928-29. Organic matter improves the working properties of soils, rendering clay soils more friable and increasing the cohesion of light soils. (See Soil Colloids and Humus.)

The temperature of the soil is affected by several circumstances. Altitude is one factor, a rise of 300 feet generally corresponding with 1° F. fall in temperature; south slopes are warmer than north slopes; red, brown, and dark-coloured soils are warmer than light-coloured soils, since they absorb more of the sun's radiant heat. The water content of the soil is, however, of principal importance. Wet soils, owing to the high specific heat of water, warm up slowly in spring and are thus late, whilst well-drained, sandy soils are early because they warm up more quickly.

Chemical Properties of Soils—The chemical properties of soils govern the supply of plant food and the presence or absence of injurious constituents. The nitrogen of the soil is almost entirely associated with the organic matter, and its supply to plants is largely regulated by the activities of bacteria, fungi, and other micro-organisms. The percentage of nitrogen in the soil is roughly one-twentieth of the organic matter. In an acre of average soil there are present within root range some thousands of pounds of nitrogen, but since the greater part is combined in the form of complex organic compounds, only a relatively small amount is available. Plants generally require their nitrogen in the form of nitrates, or, in some cases, ammonium salts. It is important, therefore, to know by what processes the complex nitrogenous compounds of the soil become changed into forms available to plants. The change to ammonium compounds is brought about by a variety of bacteria and fungi. The change of ammonium salts to nitrates takes place in two stages, one species of bacteria changing ammonium salts into nitrites, and another, which works more rapidly, changing nitrites into nitrates. The relative slowness of the ammonifying process under ordinary English conditions accounts for the very small amount of ammoniacal nitrogen present. The production of nitrates, or nitrification (*q.v.*), is favoured by warmth, aeration, and by a nearly neutral or alkaline reaction, secured by the presence of an adequate supply of lime. Nitrification is checked by low temperatures, lack of aeration, and by markedly acid soil reaction. It is obvious that by encouraging nitrification the cultivator is increasing the return on his soil nitrogen capital, and economizing expenditure on nitrogenous fertilizers. Acid soils generally show a preponderance of ammoniacal over nitrate nitrogen, a condition common to many soils in Wales, Scotland, and Ireland.

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The stock of nitrogen in the soil, except as increased by nitrogenous manuring, is maintained and increased by the action of bacteria which build up atmospheric nitrogen into organic combination. One class of nitrogen-fixing bacteria live on the roots of leguminous plants, whose favourable effect on fertility has long been known. Another class fix nitrogen on their own account, and it is to these that the principal stock of combined nitrogen in the soil is due. Nitrogen fixation by the symbiotic and by the more important free-living bacteria is favoured by the same conditions which encourage nitrification. Nitrogen may be lost from the soil as nitrates in drainage, and also by denitrification, a process which need not be feared to any great extent under ordinary agricultural conditions. (See Lysimeters.)

Phosphorus is present in the soil partly in organic combination, but principally in the form of calcium phosphates, and in some cases as aluminium and iron phosphates. These compounds are relatively insoluble. Indeed, soluble phosphates added to the soil are quickly changed to an insoluble state. Though insoluble, a proportion of the phosphorus compounds of the soil is available to plants. Since the soil solution generally contains only a very small concentration of phosphoric acid, it may be that the roots of plants take up phosphorus by direct solvent action from phosphate particles. Although phosphates are retained by the soil, it appears that the marked effect of slag dressings on poor upland pastures in Wales disappears after four or five years, owing in some cases to actual leaching of the added phosphate. In other cases reversion to highly insoluble forms may occur; this problem is still occupying attention.

Sulphur exists partly as organic sulphur compounds in the organic matter and partly as soluble sulphates; it is generally sufficient in amount in normal soils.

The other elements required by the plant are mainly associated with the colloidal clay and colloidal organic matter. (See Soil Colloids and Humus.) Colloidal clay and colloidal organic matter have the characters of weak insoluble acids, which are present partly as such and partly combined with bases, of which the most important are calcium, magnesium, potassium, and sodium. In addition, some of the calcium may be present as calcium carbonate. Potassium and calcium may be deficient in light sandy or peaty soils. Calcium is deficient in soils derived from acidic rocks under wet climates. There is a constant loss of calcium in drainage waters under British conditions, and thus, in the absence of a natural supply of calcium carbonate in the soil, the need arises for periodical applications of lime or chalk. (See Lime and Liming.)

Fertility and Infertility in Soils—We have now considered the principal properties of soils in their bearing on plant growth. Soil fertility is not any single character of a soil, but an assembly of circumstances, some of which are external to the soil itself. Indeed, behind soil fertility lie the important factors, climate and situation, controlling the general character of the husbandry which may be

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practised in a particular region.

of south-east England [illegible] suited for arable farming, whilst in the humid climate of the west of England, Wales, the west of Scotland, and Ireland, except on the lightest soils, grass husbandry is indicated.

Even considering the soil alone, fertility is no single characteristic, but rather a due balance of all those properties of the soil which affect plant growth. Thus, no scheme of manuring, however well devised, can avail alone against the deficient water supply of a coarse, sandy soil, or the deficient aeration of a water-logged clay. So far from soil fertility being merely a matter of abundance of plant food in the soil, it would probably be nearer the truth to say that the important circumstance distinguishing fertile from infertile soils is water and air supply. A soil which, by its situation and physical characteristics, can supply water and air to plants at optimum, generally has the other factors as well, for such a soil obtains from the farmer the best cultivation and manuring.

Infertility may, in the same way, be due to one or more of a number of circumstances, of which poverty in plant food is only one. The task of the scientific agriculturist is to discover in each case the limiting factor, and to find what ameliorative measures, if any, can be taken to improve it. So far as uncultivated or waste lands are concerned, the limiting factor is generally deficiency or excess of moisture. If, by any system of irrigation or drainage, these defects could be remedied, it would probably be found, in the dry soils at any rate, that the plant food factor would need attention before satisfactory crops could be obtained. Sometimes infertility may be due to lack of particular elements such as nitrogen, phosphorus, or potassium, or to the existence of sourness. Enough has been said to indicate the complexity of the conception of soil fertility, and to show that manuring is not the universal panacea for soil defects.

Soil fertility must also be considered in relation to the type of agriculture to be practised. For example, the light soils near Sandy in Bedfordshire could never have been highly fertile under grass or mixed farming, yet by building up the organic matter with heavy dressings of stable manure, and by the liberal use of fertilizers, they have become fertile for market-garden crops. On the other hand, the heavy soils of Cheshire, which might have been moderately fertile under mixed husbandry, have become rich dairy grounds through the use of bone dressings in the early nineteenth century.

Apart from the factors soil and climate, economic factors play an important part. A large centre of population naturally affects the agriculture of the region. Improvements in transport and modifications in the world's food supply may dictate changes in British agriculture, and it is important to know what are the potentialities of each soil in order that the cultivation may be rapidly adapted to changing conditions. It may be that much of the soil of west Wales, where the climate resembles that of Cornwall, might eventually find profitable utilization in growing vegetable crops. The possibilities of the mild climate of south-west Ireland for market gardening

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might also be worthy of study. Similarly, it may be possible, as a result of studies now in progress on fruit soils, to indicate extensions of our orchard lands. Poultry husbandry might be extended on light soils. Some of our poor upland grazing might be diverted from sheep to forest.

Soil Analysis—It is now realized that it is not always possible to decide as to the manurial requirements of the soil by making an analysis. Soil analysis serves two purposes. Firstly, it enables the investigator to characterize soil, to determine to what type it belongs, and to suggest improvements in its utilization. In this connexion, the mechanical analysis, setting forth the percentage of the different grades of particles, clay, silt, fine sand and coarse sand, is of the highest significance. A knowledge of the percentage of organic matter is also of great importance. Of late years, attention has been given to devising analytical methods for characterizing the moisture relationships and tillage properties of soils.

Analytical methods for the characterization of the physical properties of soil are still in a state of evolution, and this is also true of methods for determining the status of the soil with regard to plant nutrients. But whilst, so far as the former class of methods is concerned, there are indications that a generally agreed system of soil determinations will soon be evolved, the position with regard to the second class is still unsatisfactory. This is not surprising, since it involves the consideration of another group of factors connected with the plant itself. Dealing with the principal elements about which information is sought, it may be said at the outset that there is no generally received method for determining the nitrogen status of a soil. Indeed, the need or otherwise for nitrogenous manuring is more readily discerned from inspection of growing crops, and an enquiry into the past history of the soil. The phosphorus status of the soil is generally determined in this country by extracting the soil with 1 per cent. citric acid under certain prescribed conditions. Less than 0·01 per cent. of available P_2O_5 is taken as indicating deficiency. There is generally a wide penumbra of doubtful cases, and the utility of this method depends rather on the personal experience of the operator than on any sound fundamental considerations. Other weak acid solvents have been proposed for determining the content of available phosphoric acid in soils, but they are equally dependent for their value on correlation with practical experience. The same remarks apply, *mutatis mutandis*, to the determination of available potassium in the soil.

Of recent years it has been proposed to determine the plant nutrient status of soil from the composition of the seedlings grown thereon under laboratory conditions. The technique is difficult, and as yet by no means generally approved.

A discussion of the analytical methods for determining the lime status leads to the consideration of the general problem of soil sourness. (See Lime and Liming.) Although methods for determining soil

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acidity and "lime requirements" are not completely standardized, it is now possible to ascertain, with a reasonable degree of confidence, the need or otherwise for calcareous dressings on particular soils.

Altogether, soil analysis must be regarded as still in a state of development. The newer views as to the constitution of the soil have inevitably resulted in a rationalization of analytical methods, and must ultimately lead to the abandonment of methods such as the citric acid method for phosphoric acid and potash—methods which, though of admitted utility, are frankly empirical and may conceal unsuspected errors. To some extent the soil chemist must wait for progress in plant physiology, for the nature of the contract between soil and plant is not as yet completely understood.

Soil Surveys—Soil Surveys are in progress at most of the provincial agricultural institutions in the country. Formerly, when a close correspondence was assumed between geology and soil, it was thought sufficient to collect typical soil samples from different localities on an outcrop and to describe them as a soil type. More detailed methods are now in use, and in most of the survey work now in progress, Ordnance Survey maps on the scale of 6 inches to the mile are used as base maps, and the district is covered practically field by field. The work falls under three heads. First, using appropriate symbols, data as to contour, texture, stoniness, colour, water conditions, and subsoil conditions are recorded on the maps. By this means a complete description of all soil characters relevant to practice is obtained, so far as this is possible by inspection. Secondly, representative soil profiles (*i.e.*, sections showing the vertical succession of the layers of soil and subsoil) are studied and described in order to gain insight into the soil processes which have operated in the past, and which will continue to affect cultivation in the future. Thirdly, representative soil samples are taken for analysis in the laboratory in order to elucidate as far as possible the position with regard to plant nutrients. The 6-inch maps are in the nature of archives for inspection, since, except for special areas, publication would be too costly. For publication it is necessary to generalize the more important data recorded on the 6-inch maps, and obtained from analysis of soil samples.

Soils of Great Britain and Ireland—Soil surveys have been in progress in many parts of Great Britain during the past twenty years. As they have been carried out at different institutions, and until recent years, by different methods, it is somewhat difficult to give a comprehensive account of British soils. Broadly speaking, however, soil characters follow the underlying geology, although an exact correspondence is often obliterated by the occurrence of glacial drifts. In many districts we find a marked difference in agricultural value between the soils derived directly from certain rocks and the soil derived from the corresponding glacial and other drifts. The former may be dry upland soils under heath or rough grazing, whilst the latter form the fertile soils of valleys. For example, the soils derived directly from the pre-Cambrian metamorphic rocks of the Scottish

SOILS (*Continued*)—

Highlands and Ireland are of little agricultural value, whilst the corresponding drift soils are often of fair fertility.

The effect of geology is seen not only in the soils, but also in the physical features and, consequently, the climate. We may draw a broad distinction between the soils of the older Palæozoic rocks and the soils of the Mesozoic and Tertiary rocks. The former soils occupy the humid regions of south-west England, Wales, the Lake District, western Scotland, and most of Ireland, whilst the latter occupy the drier regions of the midlands and south-east of England. Whilst the former soils are generally suited to grass husbandry, the latter are more particularly marked out for arable culture. Light soils occurring in the West country may, however, be adapted to market gardening. On the other hand, heavy soils in the midlands of England, *e.g.*, Leicestershire, may be adapted for grazing.

The soils derived from the rocks and associated drifts of the Precambrian, Cambrian, Ordovician, and Silurian formations are usually stony or shaly loams of medium or light texture, rich in organic matter, and generally tending to deficiency in lime. The region occupied by these soils is mainly under grass husbandry, and comprises Cornwall, most of Wales, the Lake District, the Scottish Highlands, a great part of southern Scotland, most of Ulster, west Connacht, and east Leinster. A considerable proportion of the area of these soils is occupied by mountain, heath, and rough grazing. The soils of the Old Red Sandstone and Devonian occur in Devonshire, south-east Wales, Herefordshire, south Shropshire, parts of the Scottish Lowlands, and Munster, and form a series of reddish soils varying in texture from light loams to clays. Whilst the husbandry is generally pastoral, arable culture is more in evidence than on the soils of the older formations. The Herefordshire soils carry respectable orchards. The fertile red lands of Dunbar are light loams derived from the Old Red Sandstone. Whilst there are calcareous soils in this series, the majority of the Old Red Sandstone soils tend to deficiency in lime.

The soils of the Millstone Grit and the Carboniferous Limestone are to a large extent dry, upland grazing, as in the Peak and Pennine country. The lowland phases are fairly fertile, though, in the case of Millstone Grit, tending to sourness. Coal Measure soils occur mainly in industrial districts, and are very variable in character, though without any great extremes of texture. The greater part of Central Ireland is occupied by the Carboniferous System. Although there are great areas of bog, where drainage is defective, the better drained soils, including the glacial drifts formed from Carboniferous Limestone material, are of high fertility, as, for example, the grazing lands of Meath, West Meath, and Limerick.

The Trias, known as the New Red Sandstone, occupies a large area of the English Midlands, with extensions northwards into Cheshire and west Lancashire, into Yorkshire and Durham, and southwards into Gloucestershire, Somerset, and Devon. The associated soils are of two types, the red sandy loam of the Bunter and Keuper Sandstones, and the heavy loams and clays of the Keuper Marl. The lighter

SOILS (*Continued*)—

type, though occasionally forming barren heaths in its lighter phases, is one of the best soils for mixed husbandry, and carries in Shropshire some of the most prosperous farms in England. There is a general tendency to deficiency in lime, and in the lighter phases, potash. The heavier soils of the Keuper Marl and its derived Boulder Clay form excellent soils for mixed farming and for dairy husbandry.

The newer formations, from the Triassic to the Tertiary, give rise to soils which cannot in the present account be described in detail. They include the heavy soils of the Lias, the Oxford and Kimmeridge Clays, the Gault, the London Clay, the chalky soils of the upper Jurassic and the Chalk, the sandy soils of the Greensand, and the Bagshot and other beds of the Tertiary. Generally speaking, the textural differences are more marked than in the soils of the older formations. Under a dry climate they are, except for the heaviest clays, more used for arable culture than the soils of the north and west. They are poor in organic matter, but except for the lightest soils, are not so generally in need of lime.

G. W. R.

SOIL COLLOIDS AND HUMUS—The textbooks of agricultural science of twenty years ago presented a very simple picture of the constitution of the soil. The soil was then thought to be composed of particles of various sizes more or less loosely aggregated together and surrounded by a film of water. This water was considered to be the nutrient solution into which the root hairs of the plant "dipped," so securing by diffusion the various substances dissolved by the water from the particles. During the last fifteen or twenty years, however, a number of investigations, which had no connexion with one another in their inception, have all converged to the one general conclusion that there is some complication about the soil particles and their surrounding water which does not exist in such a system as moistened marbles or lead shot which used to be cited as illustrations of moistened soil.

For instance, some Australian workers—Green and Ampt—studied the rate at which fluids, particularly water and air, pass through columns of soil. It is known that when fluids percolate through an "ordinary" collection of particles they do so at a rate inversely proportional to their viscosities if all other conditions are the same, that is, a fluid whose viscosity is twice that of another will permeate the system at half the rate. Green and Ampt found that water, when compared with air, permeated soil at a lower rate than that corresponding to its viscosity, and the discrepancy was greater the greater the amount of clay in the soil. There was something about the soil particles which held up the water, and the investigators concluded that the surfaces of the soil particles are capable of imbibing water.

It was also shown later by Keen that when water evaporates from soil particles the rate of evaporation is less than would be calculated, and this discrepancy also increases with the clay content. The soil can "hold back" the water in a way that a collection of marbles, for instance, cannot, and this is in agreement with the conclusions of Green and Ampt.

SOIL COLLOIDS AND HUMUS (*Continued*)—

There is other evidence, which need not be described here, pointing to the same general conclusion, and in the course of a few years it became clear that there is no sharp line of division between water and soil particles in the kind of way previously thought, and as there is in a set of wet marbles, but that the nearer the water is to the centre of the particle the more firmly it is held, so that there is a transition from the "free" water outside to the solid particle through a state not unlike a jelly. It is interesting and important to notice that these peculiarities of moistened soil particles vanish after the soil has been ignited. In ignited soils and clays permeability and rate of evaporation and so forth are normal. The peculiarities themselves and the fact that they disappear after ignition are clearly explained if it is assumed that the particles have a jelly-like surface.

Soil Colloids—It has for centuries been recognized, consciously or unconsciously, that a substance may be put into one of two classes so far as its behaviour in water is concerned. Some substances—sand for instance—do not dissolve in water; others—sugar and salt, for instance—do dissolve in water. The sand remains in water in its original visible lumps which are aggregates of vast numbers of molecules; the molecules making these aggregates do not "disperse" through the water. But the original visible lumps of salt or sugar do "disperse," the molecules becoming separated and distributed as invisible units through the water. The recognition of the colloidal state is essentially a recognition of the fact that there is no clear-cut division between "dissolved" and "undissolved" particles. It is possible to have every grade of transition between the obdurate particles of a visible suspension (or, in the case of liquid particles, emulsion), and the ultimate dispersed molecules of the "true" solution. The supreme fact about the colloidal properties of soil is that soil itself provides material for the whole range of the transition. If the "particles" in a suspension of soil could be separated accurately and in great detail according to their size it would be possible to have any stage in the transition, from a suspension of rapidly falling and visible sand particles to the true solution of molecules. In between are the visible suspensions of small and slow settling silt and clay particles nearer the "sand" end of the series and the invisible aggregates of molecules—which cannot be seen by the microscope (but the larger of which can be seen by the ultramicroscope) nearer the "solution" end of the series. A solution containing these aggregates of molecules which, while vastly greater than the molecules themselves, are too small to admit of direct observation, is a colloidal solution or "sol." When the particles of such a sol are brought together into visible aggregates, *i.e.*, flocculated or coagulated, the aggregates make what is called a "gel."

In the light of these considerations it is now possible to go one stage further in describing the colloidal constitution of the soil. The soil particles exist in aggregates, and in a single aggregate there are the large macroscopic non-colloidal particles at the centre, surrounded by

SOIL COLLOIDS AND HUMUS (*Continued*)—

particles of decreasing size which shade off into a gel of colloidal particles which merges into a sol and true solution. The soil crumb which one can see and handle is a mass of such aggregates.

The Composition of Soil Colloids—During the weathering of the minerals from which the soil particles are produced certain decompositions take place which give rise to compounds, mainly composed of silica and alumina and some iron, the particles of which are of colloidal dimensions. These compounds make up the colloids which are associated with the clay in soils, and are responsible for such colloidal properties as subsoils may possess. In addition to these colloids which rise from within, so to speak, others of entirely different chemical composition are formed during the decomposition of organic matter in the soil producing a gel known as humus. (See Soils.) This humus intermingles with the mineral colloids, and the mixture of colloids is responsible for many of the important properties of the surface soil.

Soil Colloids and Base Absorption—It is very obvious that when a large particle becomes broken up into a vast number of very small particles there is a very much larger aggregate surface exposed for the same weight of material. This is responsible for many of the important properties of colloids. Surfaces in contact with solutions have very definite properties, including the property of concentrating certain of the substances in solution upon them. When particles are large and their surfaces relatively small, this effect is hardly detectable, but when the same mass of material is dispersed as particles of colloidal size the vastly greater surface will produce a marked effect. Now the colloidal constituents of the soil (humus and alumino-silica compounds) are predominantly acid, and they naturally tend to attract bases to their surface, and it is in point of fact invariably found that bases are, to some extent, removed from a solution in contact with soils, becoming attached to the colloidal particles. This is a matter of great practical importance, since the properties of a soil are very considerably affected by the kind and amount of the bases associated with the colloids.

The effect of the *kind* of bases upon soil arises from the fact that different bases have different amounts of water molecules associated with them. In most normal soils in this country the absorptive power of the soil colloids is largely satisfied with lime. If, however, the lime is replaced by soda, as does happen in certain restricted areas when the soil has been flooded by sea water or when excessive amounts of nitrate of soda have been used, the soil invariably becomes stickier because soda has much more water associated with it than lime has.

The effect of the *amount* of bases absorbed by the colloids upon soil properties is due to the fact that the less there is present the more do the acid properties of the colloids assert themselves, giving rise to the state of infertility termed "sourness."

The Flocculation of Soil Colloids—The state of aggregation of the soil particles and soil colloids is by no means permanent. Under certain conditions the colloids may be closely aggregated around the

SOIL COLLOIDS AND HUMUS (*Continued*)—

particles. Under other conditions the situation may be reversed, the colloidal particles being highly dispersed and the state of transition between the non-colloidal particles and the outer water being very great: in this condition the soil is much stickier than when the colloids are well flocculated into a gel. This is clearly a matter of great importance on heavy clay land which has a high content of colloids, and every means has to be adopted to keep the colloids as thoroughly aggregated or flocculated as possible.

Successive freezing and thawing have a marked effect upon this state of aggregation, and the furrow of a clay soil which has been exposed to successions of frosts will usually break down into a workable structure in which the colloids are highly aggregated. The reason for this effect of freezing is not quite clear, but curiously enough heating the soil has a similar effect, and whereas in the North the clay-land farmer exposes his furrows to the winter frost, the sub-tropical clay-land farmer exposes his furrows to the heat of the sun, and in each case there is a temporary coagulation of the colloids and an amelioration of the texture and an improvement in drainage.

The state of flocculation or deflocculation of the soil colloids is also greatly affected by the presence of substances in solution in the soil water. It is impossible here to go into the reasons for these effects, but the essential facts can be described quite concisely. Acids and salts tend to flocculate the soil particles so that the presence of soluble neutral salts definitely assists in some measure to improve the texture of heavy soils by flocculating the colloids, and the leaching of these salts from the soil tends towards deflocculation. Of more importance, however, is the action of bases which is in some ways more complicated. The common alkalies, soda, potash, and ammonia, deflocculate the soil colloids except when, as will be explained later, calcium is present. It is easy to show that clay particles in the absence of calcium will remain suspended almost indefinitely in water when a trace of one of the alkalies is present, a fact which has considerable application in the soil chemist's laboratory. In the absence of calcium, fertilizers which leave an alkaline residue, the chief of which is nitrate of soda, induce deflocculation and bad tilth. The alkaline earth bases, of which the only one of agricultural importance is lime, behave, however, in quite a different way from the alkalies: they coagulate the colloids and enmesh the particles in the coagulum, bringing about a great improvement in the texture of many types of clay soil. The reason for the difference between the action of the alkaline earth bases and that of the alkalies has given rise to much discussion which, however, cannot be described here, but the fact is one of great importance which every experienced clay-land farmer knows.

It must be emphasized that the improvement in texture consequent upon the flocculation of soil colloids is far from being permanent. The colloids return to the deflocculated state when the flocculating agent has been removed, and, what is more serious, they become deflocculated very easily by the mechanical action of cultivation processes, particularly if much water is present. For this reason clay land,

SOIL COLLOIDS AND HUMUS (*Continued*)—

the tilth of which has been improved by the coagulation of the colloids to the gel form, must be treated with very great care and never worked when very wet.

Soil Colloids and Soil Water—In the vast majority of soils the colloids play a major part in the determination of the state of wetness or dryness. Colloidal gels have the capacity of imbibing water with much swelling and with a tendency to become sols. This is well known, for instance, in the case of gelatine, which is a typical colloidal gel. Consequently, heavy clay soils which contain a high percentage of colloid tend to become impervious because of the swelling of the colloids which restricts the drainage channels. This action, however, is opposed by the flocculation action of lime, which, as already described, bunches the aggregates together, thereby tending to widen the channels between the aggregates. The effect of lime upon the soil colloids not only improves the ease with which the soil can be worked, but definitely facilitates its drainage.

Humus—The dark brown or black mixture of colloidal organic substances, which is designated humus, has in general much the same influence upon soil properties as the mineral colloids associated with clay. There are, however, at least two points about humus which call for special mention.

First, humus can be artificially added to the soil, or, at any rate, the organic matter which in its decomposition gives rise to humus can be added, and so far as the organic colloids are concerned it is, therefore, possible to increase the colloid content of the soil. This is a matter of practical importance, and gives rise to what at first sight is somewhat paradoxical, since the addition of humus is beneficial both to heavy clay soils and to light sandy soils. This beneficial effect upon sandy soils is quite obviously explained. One of the main troubles with sandy soils is their insufficient colloidal properties and consequent insufficient water-holding power, and the addition of humus tends towards remedying these defects. In a heavy soil the main defect would appear to be an excess of colloidal material inhibiting drainage. It must be remembered, however, that the chief method of improving this condition is to flocculate the particles by coagulating the colloids. As already described, lime reduces the stickiness of a clay soil, which stickiness is caused by the colloids, by bunching the particles together in the coagulum which it forms with those same colloids, thereby widening the drainage channels. As the colloid content is increased, the coagulum which lime will form is increased and the flocculating effect becomes more marked. Hence it is that the addition of colloidal humus to the soil which already appears to contain an excess of colloid will, in the presence of lime, bring about an improvement, because of the increased coagulum which is formed and the more marked effects of coagulation which ensue. The addition of colloidal humic matter to a soil which is inadequately limed will definitely mar the texture of a heavy soil, since the defects of texture are due to the deflocculated state of the colloid.

SOIL COLLOIDS AND HUMUS (*Continued*)—

The second distinctive feature of colloidal humus is that it has the power to "protect" the clay colloids. Colloids differ in the ease with which they can be flocculated by means of salts. The clay colloids are very sensitive and easily flocculated, humus is less sensitive and less easily flocculated. In consequence, colloids which are surrounded by humus are less easily coagulated, or conversely, more easily pass into the sol form. So it comes about that under certain circumstances, particularly in light soils, after salts have been largely leached, the colloidal clay particles surrounded or "protected" by humus will remain in the sol form under conditions in which, without the humus, they would form a gel on the surfaces of the large particles. This means that there is a much greater tendency for these protected particles to be carried downwards in the drainage water than in the absence of humus. In certain circumstances which are not clearly understood, the humus and the clay colloids which it is protecting may be deposited at lower levels as a gel, and this deposit, when it dries, gives rise to the formation of a "hard pan" which sometimes causes great difficulty in cultivation. Such pan formation on light soils can clearly be prevented by keeping the humus thoroughly coagulated as a gel by maintaining the lime status of the soil. N. M. C.

SOOT—See Fertilizers.

SOYA-BEAN CAKE AND MEAL—For composition, feeding and manurial values see Feeding Stuffs.

SPECIFIC GRAVITY—The ratio of the density of any substance, expressed in units of mass per unit volume in any system of units, to that of water at 4° C., expressed in the same system of units. Thus, in the metric system the figures expressing density and specific gravity will always be the same. When the system is changed, however, this will no longer hold, as, while the specific gravity is independent of the system of units employed, the density is not; *e.g.*, in the metric system the density of pure water at 4° C. is 1 grm. per cubic centimetre, and the specific gravity is 1·000; on changing to the foot-pound, second or British system, the density of pure water becomes 62 lbs. per cubic foot, but the specific gravity remains 1·000.

SPINACH—See Market Gardening.

STARCH EQUIVALENT SYSTEM, THE—The efforts of scientific workers during the early years of the present century to compile systems of feeding standards, by the use of which the stock-feeder should be enabled to feed his animals more efficiently and economically, drew attention to the primary need of a suitable method of defining, in common terms, both the food requirements of farm animals and the nutritive values of feeding stuffs. To assert that a given class of farm animal requires a certain number of pounds of food in its daily ration is to make a statement of no significance, since the moisture content of feeding stuffs varies within wide limits. Somewhat greater precision is attained if the requirements are given in terms of pounds of dry matter, although this method is open to the grave objection

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

that the digestibility of the dry matter of the different feeding stuffs (for example, hay and linseed cake) is widely variant. Even if the further refinement of expressing the animal's needs in terms of pounds of digestible dry matter be adopted, difficulties still arise, since the different digestible nutrients, of which the total digestible matter is composed, have varying feeding values. A pound of digestible dry matter, therefore, does not constitute a uniform standard of feeding value for all feeding stuffs.

The difficulties of the problem disappear, however, when it is borne in mind that animals are, in effect, transformers of energy and that feeding stuffs are merely sources of transformable energy. Every animal requires, for purposes of maintenance and production, a definite supply of energy in its daily food, and, within limits, it is a matter of indifference to the animal in what forms of digestible nutrients this supply of energy is provided. Metabolism studies, however, have revealed the fact that a certain fraction of the energy should be given in the form of digestible protein.

The problem confronting the investigator is to devise methods for measuring the amounts of energy available in feeding stuffs for useful purposes in the animal. Kellner's labours in this domain led up to his well-known system of starch equivalents. (O. Kellner, *Versuchs-stat.*, LIII., 1900.) *The starch equivalent of a feeding stuff is simply a measure of its content of productive energy, and is arrived at by determining the amount of fat production in the body of an adult steer when the latter, in addition to its maintenance ration, is consuming a definite allowance of the food in question.*

For the purpose of such measurements, Kellner used an instrument known as a respiration chamber. This is essentially an air-tight chamber, provided with inlet and outlet pipes, and large enough to accommodate a bullock in comfort. Air is drawn at a measured rate through the chamber, and from time to time its content of water vapour, carbon dioxide, and methane is determined. The animal wears a harness which permits of the separate collection of urine and fæces. By these means, it is possible to measure the daily output of liquid, solid, and gaseous excreta under the experimental conditions.

Kellner's procedure in his respiration chamber experiments was, first of all, to ascertain how much food, such as hay or straw, was required to maintain the weight of the bullock unchanged. In none of his experiments, however, was it possible to feed the bullocks so that their weights remained absolutely constant over the period of the experiment. Some animals gained a little fat and flesh, while others lost a little; but as the amounts gained or lost could be determined accurately by this balance method of experimentation, it was possible to make the necessary allowances in assessing the true requirements for maintenance, and, further, to introduce correction factors in the subsequent periods when the fat-producing capacities of concentrated feeding stuffs were investigated. (See Calorimetry, Animal.)

Having determined the size of the bullock's maintenance ration, Kellner then carried out a second period of feeding in which a definite

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

weight of concentrated food was added to the basal or maintenance ration. The average daily output of the different forms of excreta was ascertained, and the carbon balance (*q.v.*) in the animal was determined. The carbon retained in the body of the animal was equal to the carbon in the daily ration minus the average daily losses of carbon in the fæces, urine, carbon dioxide, and methane. Carbon retention in animals can take place in the form of fat, protein, or glycogen. In the case of a fatting bullock, however, production of glycogen can be ruled out, so that under the conditions of Kellner's experiments, the carbon was stored either as fat or protein.

The mean daily nitrogen balance during the experiment (*i.e.*, the nitrogen in the daily ration minus the mean daily output of nitrogen in the urine and fæces) gave the clue to the extent of protein storage, which, as would be expected under conditions of fattening, was never very large. Since flesh protein contains 16·7 per cent. of nitrogen, the nitrogen retention multiplied by $\frac{100}{16 \cdot 7}$ represented the amount of protein stored in the bullock. But flesh protein contains 52·5 per cent. of carbon, so that a simple calculation showed the amount of carbon stored as protein, and by subtracting this from the total carbon stored, the carbon retained as fat was ascertained. This was then converted into terms of pure fat by multiplying by $\frac{100}{77}$, since body fat contains 77 per cent. of carbon. In this way, Kellner determined how much fat was formed in the animal when a given weight of concentrated food was added to the maintenance ration. For convenience, the small amount of protein stored as flesh was converted into its isodynamic weight of fat by multiplying by the factor $\frac{5 \cdot 7}{9 \cdot 5}$ (*i.e.*, the ratio of the heats of combustion of body protein and fat), and was added to the weight of pure fat to give the total amount of production in the animal under the conditions of the experiment.

The case of linseed cake may be cited as an illustration of this type of balance experiment. Kellner found that if linseed cake were fed as a supplement to the maintenance ration, then fat (*i.e.*, pure fat plus protein expressed as fat) was formed in the body of the bullock at the rate of 18·84 lbs. per 100 lbs. of cake. In a further experiment, he found that the replacement of the cake by starch led to fat production at the rate of 25 lbs. per 100 lbs. of starch. It followed, therefore, that 100 lbs. of linseed cake had a fattening value, when fed in conjunction with maintenance rations, equal to that of 75·36 lbs. of starch. The latter figure, therefore, was the starch equivalent of linseed cake.

By repetitions of such experiments, Kellner was able to evaluate the starch equivalents of a large number of feeding stuffs, and in this way to obtain a simple numerical comparison of their productive values. Naturally, however, the determination of the starch equivalent of a feeding stuff was dependent on the possession of a respiration chamber, a very costly and elaborate instrument of which only a limited number has been built. In order, therefore, to render his

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

method more widely applicable, Kellner worked out a second method whereby the starch equivalent of a feeding stuff could be calculated from a knowledge of its content of digestible nutrients. He determined how much fat was produced in the body of a bullock when the common food nutrients, starch, sugar, protein, oil, and fibre, were added to a basal maintenance ration. The results of these trials are shown in the accompanying table:

FAT-PRODUCING CAPACITIES OF DIGESTIBLE FOOD NUTRIENTS.

Digestible Nutrient.	*Fat Production per Lb.*	*Starch Equivalent of 1 Lb. Digestible Nutrient.*
	Lb.	*Lbs.*
Starch	0·248	1
Fibre	0·253	1
Cane sugar	0·188	0·76
Glucose	0·188	0·76
Protein	0·235	0·94
Oil from oily seeds and oil cakes	0·598	2·41
Oil from cereal grains and by-products	0·526	2·12
Oil from coarse fodders and roots	0·474	1·91

The information thus obtained enabled Kellner to formulate the following expression for calculating the starch equivalent of a feeding-stuff from its digestible composition:

Starch equivalent per 100 lbs. $=[(\%$ digestible protein $\times 0{\cdot}94)+(\%$ digestible oil $\times 2{\cdot}41$, $2{\cdot}12$, or $1{\cdot}91)+\%$ digestible carbohydrate $+$digestible fibre$]\times$V.

Obviously the factor to be employed for converting the oily constituent into its equivalent of starch will depend upon the nature of the feeding stuff. (See Table.) It will be noted that a correction factor V, known as the percentage availability of the feeding stuff, is introduced into the expression. The necessity for this followed the discovery that if the calculated starch equivalent of any feeding stuff be checked against the value obtained by actual experiment on a bullock in the respiration chamber, the latter is always smaller than the figure predicted by calculation. The discrepancy is of widely varying magnitude for different feeding stuffs. In the case of linseed cake, for example, the experimental starch equivalent is 97 per cent.; for barley meal, 98 per cent.; for swedes, 85 per cent.; for bran, 77 per cent.; for good meadow hay, 67 per cent.; and for oat straw, 43 per cent. (of the calculated value). When calculating the starch equivalent of a feeding stuff, therefore, it is necessary to multiply the sum of the starch equivalents of the digestible nutrients by the availability factor in order to obtain a value identical with that which would be obtained by the use of the respiration chamber.

The reason for the discrepancy between the calculated and the experimental values is simple. The starch equivalents of the digestible nutrients were determined by feeding these constituents in the pure condition. In practice, however, the digestible nutrients are not fed

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

in this condition, but are embedded in the indigestible matter of feeding stuffs. The animal must expend energy in dealing with this indigestible portion of the food. The non-utilizable part must be masticated; it must be separated from the utilizable part during digestion; it must be passed along the alimentary tract for elimination. All these processes entail expenditure of energy by the animal, the effect being to reduce in a greater or less degree, dependent on the digestibility of the food, the amount of energy which the animal should otherwise be able to derive from the digestible nutrients of the feeding stuff. Thus, when calculating the starch equivalent of a feeding stuff, the digestible nutrients are first given their full value and a correction is then applied for the energy expended in masticating and digesting the food.

With concentrated foods of high digestibility, the necessary correction is not very large, V usually lying between 90 and 100 per cent. With coarse fodders, on the other hand, containing high percentages of indigestible fibre, the correction may be very big. In such cases, it is not advisable to rely on the factor V, but to base the correction on the content of crude fibre. By examining the fat-producing capacities of different hays and straws, Kellner found that every pound of fibre caused the true starch equivalent to be 0·58 lb. less than that calculated on the basis of digestible composition. If the coarse fodder were chaffed before use, the reduction was only 0·29 lb. of starch equivalent per pound of fibre, since chaffing diminished the energy required for mastication and digestion. When calculating the starch equivalent of a coarse fodder, therefore, it is customary to add together the starch equivalents of the digestible nutrients and to subtract from this 0·58 times the percentage of crude fibre, if the fodder is fed in the long condition, or, if chaffed before feeding, only 0·29 times the crude fibre content. With green fodders, the proportion of crude fibre to be subtracted varies with the fibre content of the food according to the scheme set out in the accompanying table.

CORRECTION FACTORS FOR CALCULATING STARCH EQUIVALENTS OF ROUGHAGES AND GREEN FODDERS.

	Proportion of Total Crude Fibre to be Subtracted from Sum of Starch Equivalents of Digestible Nutrients.
Coarse fodders (unchaffed)	0·58
,, ,, (chaffed)	0·29
Green fodders with more than 16 per cent. fibre	0·58
14 ,, ,,	0·53
12	0·48
10	0·43
8	0·38
6	0·34
4	0·29

It is important to emphasize again that the starch equivalent assessment of nutritive value is based on fat production in the animal. One pound of starch equivalent can produce ¼ lb. of fat (or fat plus

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

protein expressed as fat). This corresponds with a storage of 1,071 Calories in the animal. The starch equivalent of maize is 81. This signifies that 100 lbs. of maize, if fed in conjunction with maintenance rations, will produce about 20¼ lbs. of fat in the body of the fattening *ruminant*. Emphasis is placed on the word ruminant, since there is no valid reason for assuming that a pound of starch equivalent will have for the non-ruminant animal, such as the pig, the same fattening value as for the ruminant. This error is frequently made, however, since it is liable to be forgotten that Kellner's fundamental work was carried out on fattening bullocks. There is strong evidence from recent investigations that 1 lb. of starch equivalent can form 1,500 Calories (=0·35 lb. fat) in the body of a pig as against 1,071 Calories (=0·25 lb. fat) in the body of the ruminant (T. B. Wood, *J. Agric. Sci.*, xvi., 425, 1926). Care should also be exercised in considering the significance of starch equivalents in relation to the rationing of dairy cows. Kellner discovered that the digestible nutrients of feeding stuffs are utilized with a 25 per cent. greater efficiency for milk production than for fat production. In other words, whereas 1 lb. of starch equivalent leads to a storage of 1,071 Calories in the form of fat, it will, if fed to a dairy cow in the production part of the ration, give rise to the production of 1,350 Calories in the form of milk (=0·45 gallon of milk containing 3·7 per cent. of fat). In the case of milk production, it should also be kept in mind that a definite fraction of the starch equivalent should be supplied in the form of digestible protein.

It now merely remains to inquire as to how far the production values attributed to feeding stuffs by Kellner in the form of starch equivalents agree with the results of practical experience. No serious criticism can be levelled against the values given to the concentrated feeding stuffs. In practice, their effects in fattening are such as would be predicted from a consideration of their starch equivalents. Moreover, the nutritive values ascribed to them in the starch equivalent system agree very satisfactorily with the productive values as worked out from an essentially different method of experimentation. The starch equivalent of a concentrate multiplied by 1,071 (the net energy value of 1 lb. of starch) usually gives a number of calories agreeing fairly well with the net energy value of the concentrate as derived by Armsby.

With the coarse fodders, however, the case is different. It would appear that, in general, the various forms of hay have a greater productive value in feeding practice than would be anticipated from the starch equivalents attributed to them by Kellner. It must be confessed that the method of correcting the starch equivalents of such fodders on the basis of fibre content is somewhat arbitrary. The magnitude of the correction is possibly too high in most cases, a conjecture which is strengthened by the fact that Armsby's net energy values for coarse fodders, the determination of which does not involve the use of such arbitrary correction factors, are on the whole distinctly higher than Kellner's figures. These considerations led the late Professor T. B. Wood, in the 1927 edition of "Rations

STARCH EQUIVALENT SYSTEM, THE (*Continued*)—

for Live Stock" (*Min. Agric. and Fish.*, Misc. Pub., No. 32), to raise the starch equivalents of all kinds of hay and straw by one-fifth.

Disproportionate significance should not, however, be attached to this criticism in respect of Kellner's starch equivalents for the coarse fodders. After all, such fodders are not commonly used for productive purposes, but furnish the nutrients for maintenance. Their nutritive value should therefore be assessed on the basis of their value in the maintenance functions, and for this purpose the following expression, worked out from the heat-producing capacities of the digestible nutrients, may be employed:

Maintenance starch equivalent per 100 lbs. =[(% digestible protein × 1·25) + (% digestible oil × 2·3) + % digestible carbohydrate + digestible fibre].

By means of this expression it is possible to compare the fuel values of the coarse fodders. It should be pointed out that the maintenance starch equivalent is, in reality, another way of expressing Armsby's metabolizable energy, just as the ordinary production starch equivalent connotes the same idea as Armsby's net energy value. One pound of starch or starch equivalent contains 1,707 Calories of metabolizable energy.

H. E. W.

STEELYARD—A simple portable weighing apparatus suited for weighing objects of moderate weight, for which the transport of a suitable balance would be awkward. There are two types, the *British* and the *Danish*. The *British steelyard* consists of a steel beam pivoted, or better provided with a knife edge, near one end, at which is a counterpoise and a hook near the pivot, from which the article to be weighed can be hung. A small weight is then moved along the arm at the other side of the pivot until a balance is obtained, the weight being read off on graduations on this arm. The steelyard should be suspended from a support while weighing is in progress. In the *Danish steelyard* there is a fixed weight at one end of the steel beam and a hook at the other, to which the article to be weighed is attached, while the suspension knife-edge is moved along the beam until a balance seems to be attained on raising from the ground. The weight is then read off from graduations along the beam. An ancient Lapland riddle enquires, "What is that which cannot lie?" The answer is "Bismar," the Danish steelyard, but, unfortunately, this implied compliment is anything but substantiated in practice, and in weighing objects appreciably lighter than the fixed weight on the steelyard a skilful operator can make it appear to balance at a point considerably less than the true weight. Since, if it be raised with approximately constant acceleration, both unknown weight and fixed weight are in effect augmented in like proportions, and since the former is operating at the end of the greater arm, the moment about the fulcrum is increased on this side, with the result that balance is apparently obtained at less than the true weight. This steelyard was used in olden times in England under the name of the "Auncel," but its use was forbidden by law in the reign of Edward III. The British steelyard is not

STEELYARD (*Continued*)—
subject to this defect, as, in the first place, it is normally hung from a support, and even if not the index weight is adjusted while it is held steady in the hand. (See Balance; Weighbridge.)

STERILIZATION (OF MILK)—See Milk; and Milk and Milk Products, Bacteriology of.

STORAGE AND TRANSPORT—For consideration of bearing on these problems see Refrigeration.

STRAW, Barley, Oats, Wheat and Rye—For problems associated with character of straw see separate articles on each cereal; for composition and feeding value see Feeding Stuffs; for manurial value see Feeding Stuffs, The Manurial Value of.

STRAWBERRY—See Soft Fruits, under Fruit.

SUBTERRANEAN CLOVER—See Legumes, Breeding of Herbage.

SUGAR-BEET—Introductory—During the nineteenth century spasmodic attempts were made to establish a beet-sugar industry in England, but it was not until 1912, when the Cantley (Norfolk) factory was opened, that an appreciable increase in sugar-beet sowings took place. Previous to 1912 the sugar-beet from the negligible English crop was shipped to the Continent for extraction, but as soon as the Cantley factory was built the acreage increased from 500 to 4,000 acres, and the industry presented a different outlook to prospective growers. The early days of the Cantley factory were anxious ones for financially interested persons, and the factory was closed for a time (1916-1919), which resulted in the English beet acreage becoming negligible once more.

In 1920, however, operations were restarted at Cantley, and in the following year the Kelham factory, near Newark, was built and began to work.

But it was the Government subsidy on home-produced sugar, set up in 1924, that gave the fillip to the British beet-sugar industry, and from that time the acreage has increased by leaps and bounds until in 1929 there were 230,000 acres, and the estimated acreage for 1930 was 315,000 acres. Except in 1928, the year following a bad crop in 1927, development has been well sustained, as is shown in the following table (compare Bridges and Dixey, *J.R.A.S.E.*, vol. lxxxvi., 69).

Year.	*Acres of Beet.*
Before 1912	Less than 500
1912–1916	About 4,000
1916–1919	150–170
1920	3,017
1921	8,333
1922	8,409
1923	16,918
1924	22,637
1925	56,243
1926	129,463
1927	232,918
1928	178,049
1929	231,749
1930	346,700*

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* *J. Min. Agric. and Fish.*

SUGAR-BEET (*Continued*)—

There has been a beet-sugar industry on the Continent for over a hundred years, and practical and scientific lessons drawn therefrom have greatly assisted in establishing the crop in the British Isles.

The great improvement of varieties and strains effected over a period of many years by such men as Achard, Louis and Jacques de Vilmorin, and Munerati (see Sugar-Beet Crop, History of the Improvement of the), has saved the British industry the necessity for such laborious investigations, and, while there is still much testing of strains under British conditions to be done, the more important problems are concerned with cultural methods and the absorption of the crop into the systems of farming practised in this country. It is with these more practical aspects that this article is chiefly concerned.

Position in Farm Rotation—Sugar-beet has not yet settled down to a definite place in the farm rotation, and has been confined, as might be expected, to a replacement of the existing crops in the root break. The Farm Economics Branch of the University of Cambridge, in Report No. 13, which records the costings of over a hundred farms in the Eastern Counties of England, gives instances of practically every crop preceding beet: barley, wheat, oats, hay, mustard, and other root crops are quoted, and sugar-beet itself in 1929 was the preceding crop in 19 per cent. of the fields examined. This information illustrates the adaptability of sugar-beet to most situations on arable farms; it can, in fact, be grown successfully after all the common crops. This has been recognized by British growers who have paid little regard to the preceding crop and grown sugar-beet at convenient situations for the workman and for haulage off the land; in other words, in situations where cultivation has been easiest. Such methods cannot continue, for if beet is to remain in British farming, it must take a fixed place in the general economy of the holding, or such factors as the accumulation of bacterial and fungoid disease, the ravages of insect pests, the continued interference with the rest of the cropping and disorganization of the farm labour, may defeat its purpose. Fortunately, there are signs that growers have appreciated these matters, and the tendency now is to try and fit sugar-beet into the root shift. This is its natural place, but if the acreage continues to increase, it is obvious that smaller areas of swedes and mangolds will be grown in the future, and that systems of stock feeding involving the use of less roots will be adopted.

Such a policy removes some of the competition for labour that sugar-beet meets from other root crops at singling, hoeing, and lifting, and decreases the need for casual labour. About half the root shift under sugar-beet on a four-course arable farm can be handled by the usual number of men employed, provided they are paid piece-work rates. Beyond this proportion casual labour will be required, but the extent to which it is necessary is not nearly so great as is imagined. Even when the whole of the roots are sugar-beet, it is rarely necessary to employ more than two extra men per 25 acres of beet.

If there is no winter corn to drill, and tractor power is available for

SUGAR-BEET (*Continued*)—

stubble cleaning, further labour is relieved for work on the beet: in fact, a policy of sugar-beet and spring corn, although obviously impracticable on wheat-growing soils, fits very well indeed on lighter soils, and in dry districts.

The cost of producing a ton of beet has been shown repeatedly to decrease as the tonnage per acre increases. As an illustration, the Cambridge costings in the Eastern Counties in 1927 show that a yield of 4 tons per acre produced a net loss of £8 per acre; a yield of just under 7 tons per acre showed neither profit nor loss; but there was a profit of £11 from a yield of 11 tons per acre. Since these 1927 contracts, the price of beet has become appreciably reduced, and the yield, therefore, at which losses cease and profit begins has become higher than 7 tons per arce, and is likely to become still higher if the price per ton of beet becomes lower. But yield and profit are to a great extent a matter of soil.

Soils—Sugar-beet soils have been examined from this point of view by the Cambridge economists, who have shown that the fens, warp soils, and silts are the best, followed in order by the light to medium soils, the medium to heavy, and, lastly, the very light soils, *i.e.*, those that have for generations been on the verge of cultivation, and which, in some cases, have been broken up specially to grow beet. There are few British soils incapable of growing beet, excepting those devoid of lime, but there are those where beet-growing is not likely to be profitable in the near future. The yield limitations of the very light soils, the high dirt tare that is inevitable with present methods on the heavy soils, and the consequent higher freight charges per ton of beet delivered, the difficulty in hauling beet off heavy land, except early in the seasons, limit the possibilities of remunerative financial returns from beet on these soils.

Beet cultivation is easier on the lighter land, but it does not necessarily follow that production costs per ton of beet on these soils are low; they may be quite high, for the lighter land beet soils must be able to retain sufficient moisture and manure to prevent serious checks in growth, and therefore low yields, during times of rainfall deficiency. Shallow soils are not suitable, for the sugar-beet plant ranges both widely and deeply into the soil, and deep tillage, impossible where the underlying rock is near the surface, is necessary if shapely beet are to be grown. A good shape is important—irregularly shaped and fangy roots being costly to pull and knock.

The good fens grow high yields of rather low quality beet; they are, nevertheless, very suitable sugar-beet soils. The sandy fens with a peaty and not a clay subsoil are not good. The lime requirement of these soils is very high, and both yield and sugar content are inclined to be low. Fortunately, there are very few of such soils in England, although there is one beet factory surrounded by them. The best beet soil, if such can be defined, is a deep medium to light loam, with a retentive subsoil and an adequate lime content. (See Mangolds.)

Climatic Requirements—The best results have been obtained in seasons when the rainfall over the growing period has been slightly below

SUGAR-BEET (*Continued*)—

and the sunshine slightly above the normal for the country. In East Anglia the normal March, April, and May rainfall is sufficient to grow the crop well, but it is important that May and June should maintain their averages. Occasional showers, in no greater quantity than will keep the crop going, are all that is required for the remainder of the season. When the weather in September, October, and November is congenial, not only are lifting and hauling costs per ton of beet reduced, but the beet will continue to put on weight, if they have been well treated, until frosts set in. If the weather is good, yield will increase even in the early part of November, and if left undisturbed in the ground, beet will usually take little harm from frost. The sugar content, however, becomes lower as the season proceeds.

Varieties—Little detailed information is yet available regarding the strains of beet best suited to British conditions. The varieties and strains offered by the factories are of Continental origin, and there are usually three strains of each variety—a high yielding (E) type of rather low sugar content; a lower yielding (Z) type of rather higher sugar content; and one that is intermediate between the two (N) in both yield and sugar content.

Trials of strains of sugar-beet were carried out by the National Institute of Agricultural Botany at three centres in England during each of the three years 1927 to 1929. In these trials as much as 3 tons more washed beet was grown by the best than by the worst strain. The yields of washed beet, taken from the averages of three years, varied from 9 tons 17 cwts. to 13 tons per acre, and the sugar contents from 17·3 per cent. to 19 per cent., the highest yielders having the lowest sugar content, and the lowest yielders the highest sugar content. The monetary return varied from £28 5s. to £33 15s. per acre, the average yield of the trial area being over 4 tons of washed beet to the acre more than the average yield of the whole country—an important matter when contemplating general conclusions from the figures.

The table on p. 1163, which is reproduced by permission of the Director of the National Institute of Agricultural Botany, is important.

Kleinwanzleben E is a very reliable strain. Even in a poor sugar year like 1927, when an E strain might have been expected to return the least money per acre, it was still the best. In that year the average sugar content of all the strains tested was 16·97 per cent.; that of Kleinwanzleben E was 16·5 per cent., and that of the highest Z strain was 18·1 per cent., but the much higher tonnage from the Kleinwanzleben E more than compensated for the lower sugar content. All the beet factories which by contract agreements supply the seed of whatever strains seem to be suitable have not yet offered E strains to their growers, but it is to the growers' interests that this step should be taken immediately. Kleinwanzleben E, of those so far tested, is the best, except perhaps on heavy land where Dippe E gave better results. On the light lands the superiority of Kleinwanzleben E is undoubted—indeed, this strain may be used with a reasonable prospect

SUGAR-BEET (*Continued*)—

of success on all soils. On the fens and silts, however, a heavy top may develop and a small-topped variety of rather higher sugar content, like Kuhn P or Marsters, is perhaps more suited to the fens, although the heavier yielding E strains have done remarkably well at these situations in years favourable for sugar development. The evidence of the trials of the National Institute of Agricultural Botany points conclusively to the use of Kuhn P or Marsters seed for the very early sowings, mainly because they are nearly non-bolting strains, but the main seeding should be either Kleinwanzleben, Dippe, or Strube, and the E strains should be used. Light land beet growers had been successful with the combination of Kuhn P and Kleinwanzleben N before the report of these trials was issued. The modification now suggested is the substitution of the E for the N strain for part of the acreage at least.

General Average of Sugar-Beets per Acre.

(*Average of Three Years' Trials at Three Stations*, 1927–1929.)

Strain.	*Average Weight of Washed Beet Produced.*	*Average Sugar Content.*	*General Average Value of Roots per Acre.*		
	Tons per Acre.	Per Cent.	£	s.	d.
Kleinwanzleben E	13·07	17·3	33	15	3
Dippe E	12·81	17·3	33	1	10
Strube E	11·83	18·1	32	2	9
Hoerning H.S.	12·23	17·5	32	0	0
Zapotil 11	11·76	18·1	31	18	11
Gartons' 426	11·82	18·0	31	18	3
Kuhn P	11·56	18·0	31	4	3
Schreiber S.S.	11·51	17·8	30	13	10
Marsters	10·98	18·5	30	11	2
Vilmorin B.	11·74	17·4	30	10	6
Janasz	9·87	19·0	28	5	11

Cultivation—Clean land is more essential for sugar-beet than for other root crops, for if the best crops are to be grown row distances must be too small for any cleaning, such as is possible amongst mangolds, and especially swedes, to be really successful. Where a choice between these crops can be made the sugar-beet should be given the clean land, or, if it must be grown on foul land, distances as wide as 24 ins. may be used. As a rule, 18 to 21 in. rows are sufficiently wide. In any case it is essential that the cultivation for the crop should begin in the autumn, and, whether the stubble is clean or not, it should be broken to germinate as many as possible of the annual weeds, and to allow the autumn rain to penetrate. The land should then be broken up deeply, the depth should be at least 10 ins., and the operation performed before Christmas. The method to be used in this deep tillage is not in general agreement, but it must be obtained either by subsoiling or deep ploughing. The difficulties of subsoiling are practical

SUGAR-BEET (*Continued*)—

ones, for there is no implement that will subsoil completely, *i.e.*, will break the whole of the soil below the ploughing level to the required depth. Subsoil tines are nothing but a compromise, and subsoil ploughs, confined to one purpose only, are usually an outlay that the average farmer endeavours to avoid. A second plough, with the breast removed and fitted with a worn share, or one with a broken wing, is as good as anything, but even then the work is rarely done sufficiently thoroughly to satisfy a really critical examination. It is comparatively easy to work a foot deep when subsoiling, but not so easy when ploughing. Deep ploughing, however, breaks the whole of the soil, but it inverts it and may bring raw soil and dormant weed seeds to the surface. The weeds, however, are usually killed during the subsequent hoeing, and there are, fortunately, few situations where the inversion of soil is serious. Deep ploughing, therefore, is usually preferable to shallower ploughing combined with subsoil ploughing, and, moreover, it saves the work of a horse and a man. The Continental sugar-beet ploughs and the English digger ploughs developed for the sugar-beet crop are satisfactory, but the land, after ploughing, must be left level and the furrows ploughed back. It is essential to plough early, and even if the land be free working, to see that the winter mould is not lost by late ploughings being done too deeply. One really deep ploughing, provided the land is not panned by the winter rains, is usually all that is required. If it is felt necessary to plough again—and such matters can only be decided on the spot—the second ploughing should be shallow. Farmyard manure should be ploughed down early, and although well-rotted dung is easier to cover, long manure, even when ploughed down late, does not necessarily cause fangy beet as is commonly supposed.

Engledow and others produce detailed evidence of the importance of "plant" on yield, and although in these investigations yield increased up to the highest "plant" population recorded, it is evident that it is possible to have too many plants (*J. Agric. Sci.*, October, 1928). For every field there is a "plant" population best measured in numbers of plants per acre, which will give the highest yield of sugar per acre. It is suggested that at least 30,000 plants to the acre should be the object on all soils, and that rather higher plant populations are desirable on the very light, sandy soils, and rather less can be grown on the better soils, such as the fens, the silts, and the medium loams in good condition, without materially affecting yield. Nevertheless, for safety it is well to aim always at not less than 30,000 plants to the acre. But it must be remembered that the size of individual beets has a profound effect upon the ease, efficiency, and, therefore, the cost of handling a crop at lifting. Too many plants upon land in poor heart may result in a lower yield and an increased cost; small beet of ½ lb. or so in weight do not knock so easily, more dirt adheres, and more freightage charges are thereby incurred; neither are they so easily topped and loaded as a medium-sized beet of about a pound each. The lightest sandy soils are exceptional. There a dense plant is required or the land is never completely shaded by the leaves, and a

SUGAR-BEET (*Continued*)—

small plant population can never make up in size what has been lost by numbers. But in spite of the strongest recommendations to aim at a high plant population the general average of the country, as calculated by the factories from their returns, is astonishingly low.

The arrangement of the optimum plant population affects the seed rate, the ease of singling and cleaning by hand, as well as the horse-hoeing, and many trials of row-widths have been made in England since beet was introduced. Differences in yield from these trials have been demonstrated. For instance, rows of beet drilled at 18 ins. apart have yielded higher than rows drilled at 24 ins. apart. But these differences, apparently due to the various drill coulter spacings, can be explained, invariably, by the variation in plant population, for the yield varies with the number of plants irrespective of the distance between the rows. Considered from the opposite viewpoint, it would be expected, therefore, that the same population on rows of 15, 18, 21, or 24 ins. would give the same yield. This is an almost impossible trial to conduct, but it has been attempted once at least—in 1929 in Norfolk at seven trial centres where the spacing to obtain the standard of 30,000 plants per acre was done by hand and the distance between each plant measured before spacing. The results are given, for they illustrate several points of interest:

Row Distances.

	15 *Ins.*	18 *Ins.*	21 *Ins.*	24 *Ins.*
Number of beets per acre ..	28,810	27,910	27,200	25,640
Yield per acre (tons)	12·2	12·0	11·7	11·2
Percentage of sugar	18·0	17·8	18·0	17·8
Numbers of plants as percentage of numbers on 24 in. rows	112	109	106	100
Yield as percentage of yield of 24 in. rows	109	107	104	100
Mean weight per beet (lbs.) ..	0·95	0·97	0·98	1·03

It is evident that a 30,000 plant population is not easy to obtain, that it becomes easier as the rows become closer, and that yield, sugar content, and weight of individual beet are controlled by row distance only in so far as this affects the number of plants.

The same principles hold with drilling on the ridge; almost without exception, where crops drilled on the ridge have yielded higher in English trials than crops drilled on the flat, they have possessed more plants, and the same is equally true when the results have been reversed. If a full plant can be relied upon from ridged work, there is no reason why the practice should not be adopted, for hand-hoeing, horse-hoeing, singling, and cleaning will then be easier. But a good plant is more often established on the flat than on the ridge, especially in dry districts and late in the sowing period. Moreover, close ridges are very difficult to draw, and close rows, as already mentioned, are

SUGAR-BEET (*Continued*)—

Manuring—Sugar-beet is essentially a crop that the high farmer will grow best. Its widespread root range, comparatively late time of sowing, and short growing period not only necessitate an ample manurial supply, but one that is quickly and continuously available. But good crops of beet depend as much, if not more, upon the residues of previous farming as upon the immediate application of readily soluble manures. This is why beet fits so readily into the intensively farmed districts, and is one of the reasons why the Dutch beet yields are so much higher than the British yields. It is, therefore, unreasonable to expect high yields at once from a sudden change to intensive methods of manuring. Artificial manures, however, will produce profitable increases in the yield of sugar-beet, provided the correct principles are followed. It is necessary to lime if the land needs it, and then to combine one or other of the phosphatic, potassic, and nitrogenous manures into a complete mixture of artificials, and to vary the quantity of each ingredient according to the known character of the soil. Sugar-beet responds very readily to nitrogenous manures on all except fen soils. On most sugar-beet soils, since they are mainly light, a response will be obtained from potash manures: but beet is less responsive to phosphates, although the inclusion of these fertilizers is justified, if only on account of their great value in promoting root development and early establishment of plant.

Farmers who believe in manuring the rotation rather than the crop —an outlook to be commended—take the convenient opportunity afforded by the root break of applying a complete mixture of artificials to the land. In this manner sugar-beet will automatically receive a complete dressing of artificials. Superphosphate is the most effective form of phosphatic manure, and kainit, on all but the heavy soils, and muriate or sulphate of potash, or 30 per cent. potash salts, are reliable forms of potash. All the usual quick-acting nitrogenous manures are effective. Having applied about 12 tons of dung to the acre, a mixture composed of the following artificials may be taken as a type around which to make any necessary variations:

3 cwts. superphosphate per acre.
1 cwt. muriate of potash per acre.
2 cwts. sulphate of ammonia per acre.

Top-dress, not later than singling, with 1 cwt. of nitrate of soda.

The superphosphate should be increased on the heavier soils and the potash reduced. Some light soils will require up to 2 cwts. of muriate of potash, or equivalent quantity of kainit; the amount of potash, according to Rothamsted trials, should increase as the quantity of nitrogenous manure increases. But even on the light gravelly soils at the Norfolk Agricultural Station, when as much as 3 cwts. per acre of nitrate of soda has been used, there has been no response to more than 2 cwts. of muriate of potash. Fen soils do not require any nitrogenous manure. Time is saved if the whole of the artificials can be put on the seed-bed, and late top-dressing, which delays ripening, and may therefore reduce the sugar content, is avoided. Top-dressing

SUGAR-BEET *(Continued)*—

need not be practised except on the lightest soils, where sulphate of ammonia on the seed-bed and nitrate of soda at singling is a sound combination. But since nitrate of soda is a most effective source of nitrogen for sugar-beet, and is usually a part, if not the whole, of the nitrogenous manuring, its entire use on the seed-bed may be questoned. At the Norfolk Agricultural Station the time of application of this manure on dunged land supplemented with phosphates and potash has been investigated over a three-year period (1927-1929) with the following results:

3 *Cwts. of Nitrate of Soda Applied.*	*Weight of Washed Beet per Acre.*		*Sugar Content.*
	Tons.	Cwts.	Per Cent.
On the seed-bed	12	16	17·9
Half on the seed-bed Half at singling	12	13	17·9
One-third on the seed-bed, one-third at singling, and one-third three weeks later	12	17	17·8
No nitrogenous manure	11	0	18·2

If nitrate of soda is mixed with superphosphate it should be applied at once.

On the light soils in districts of rather low rainfall, up to 3 cwts. of nitrate of soda with dung has proved profitable, but according to the trials conducted in the West of England this high quantity is not justified in that area, and 1 to 2 cwts. only are recommended. But, whatever quantity is used and in whatever district, the time of application is of paramount importance. It must not be later than at the time of singling, but the whole may be put on the seed-bed with perfect safety on all but the lightest soils, and perhaps in the wetter districts.

If no dung is available, each ingredient of the complete mixture given above should be increased proportionately, and from 8 to 10 cwts. per acre used.

Lifting—Hand-lifting of beet is not often practised by British beet growers, but it is not much slower on piece work than pulling and knocking behind a lifting implement, and it has the advantage that the dirt tare is not so high and the land is easier to cart over, which is important in a wet autumn. Several types of lifters have been tried, but the ideal has not yet appeared. Some kinds will not work in heavy ground, under which circumstances an ordinary plough is as good as anything; others plough out too much soil and make carting difficult, or press the soil on to the beet and make it less easy to remove by knocking, while another type will not allow the long inflorescences of the bolters to pass the machine blocks, and the team must stop while they are cleared. There is really little to choose between the various lifters on the market, provided attention is confined to lifters alone.

SUGAR-BEET (*Continued*)—

Combined harvesters to lift, top, and clean can be bought at a high price, but not one of those available at present is even reasonably good, for they top badly and frequently leave beet in the ground, besides being heavy in draught and hopelessly high in price. If, however, a machine could be designed to do this work properly, it would be a forward step of great value. At present pulling, knocking, and topping is essentially a hand operation; from four to six rows are pulled, knocked, and put into one row, and then topped by hand. It is well worth remembering at this stage that if the tops are to be fed—and this is by far the most profitable means of disposal—their cleanliness is a big factor in the essential feeding value.

On some soils it pays to put the lifter through the crop, and to allow the beet so loosened to stand a few days before they are pulled and knocked. On other soils this is not effective, for there are many places where the soil is most easily removed if the beet are knocked immediately after the lifter.

Valuable developments are likely to take place in road transport, and already companies have been formed with the prime object of carting sugar-beet. As methods of loading are improved, delivery from roadside to the factory, by far the most convenient method, is likely to decrease the cost of transport and to enable the grower to handle more acres of beet on his farm.

Growers are asked by the factories to top the beet below the level of the lowest leaf scar, and although there are several other reasons for this request, perhaps the most important is that the beet are thereby prevented from sending out shoots when stored in the beet dumps at the factory. Similarly, storage on the farms, which would extend the period of factory operation, seems a likely development in the future. If so, bad topping leading to shoot formation in the clamps would cause rapid and great loss of sugar before the crop reached the factory.

Financial Results—Under the artificial conditions introduced by the subsidy the financial results of sugar-beet have been encouraging. On sheep farms it is no uncommon occurrence for the ewe flock to be kept on sugar-beet tops from the beginning of lifting till lambing starts in January, or the bullocks to be fed on tops with no other roots until Christmas, and then finished on beet pulp as a root substitute. The by-products are important in the economy of the crop, but it is unlikely that the British farmer will be satisfied with them alone as his profit. Sugar-beet, however is a cash root crop, and any survey of its financial possibilities must comprehend the possible cropping alternatives. Is the situation, for instance, suited to potato growing? Is there a handy market for such things as brussels sprouts? Will beet bring in as much money as carrots in the carrot-growing districts, and so on? Judged by the last few years, beet is not likely to interfere seriously with any one of these crops where its cultivation has become well established. There will undoubtedly be fluctuations from time to time, according to bad and good years, but beet so far has

SUGAR-BEET (*Continued*)—

not proved a serious competitor for other cash root crops. The possibility of profit from beet, as already inferred, on the less suitable soils, will go as soon as the subsidy ends, for it seems inevitable that prices will then be much lower. As soon as the prices approximate to the Continental standard, it will only be the best land in the country that will justify the beet crop. Detailed attention has been given to the cost of growing sugar beet, and the following figures, taken from *Report No.* 13 *Farm Economics Branch, Cambridge Department of Agriculture,* put the situation clearly for 1927, a low-yielding year, and 1928, a higher yielding year:

Over-All Receipts and Profits per Acre in 1927 and 1928.

	1927.	1928.
Number of fields..	172	167
Average washed yield	7·711 tons	9·035 tons
Average sugar content	16·1 per cent.	17·9 per cent.

Costs and Receipts per Acre.

	£	s.	d.	£.	s.	d
Total cash cost	21	1	4¼	21	8	4¾
Gross cash receipts	21	6	9¾	24	4	8¾
Cash profit		5	5½	2	16	4
Credit for tops and net residual values of cultivations and manures	3	18	7½	4	3	5¼
Net profit	4	4	1	6	19	9¼

A large proportion of the profit in both years is in the form of credit for tops, residues of manures, and cultivations during two years when the yields and prices per ton of the costed crops were 7·7 tons selling at 55s. 4d. per ton, and 9 tons selling at 43s. 7d. per ton. If price must go down, yield must go up, and there are soils where even 7 tons per acre is not always obtainable. But if the price can settle down so that a profit is still possible on those lands whose natural features limit the yield to 8 or 9 tons per acre of washed beet, then a new British arable farming may easily develop, for there is abundant evidence that the arable farms of the "sheep and barley land" type can be farmed with fewer mangolds and swedes in the root shift provided the remainder of the root break is put in with sugar-beet. It is quite easy to keep the requisite head of stock on less stock-feeding roots provided the use of the tops and dried pulp is understood. But it seems more likely that nothing less than a 10 ton crop of washed beet will meet the case. If so, the outlook is not very bright, for there are so many soils in Britain where such a yield, low as it may seem to Continental farmers, is almost impossible, no matter how good the farming may be; for that reason the beet crop does not seem to be the solution to the arable problem that everyone is seeking, unless refuge may be found in a statement taken from the Cambridge Farm Economic Reports (*loc. cit.*) :

SUGAR-BEET (*Continued*)—

"On expiry of the subsidy growers must decide not how much loss beet will incur, but how much less beet growing will lose than other forms of fallow crops."

That is not very encouraging to a new industry. F. R.

SUGAR-BEET CROP, HISTORY OF THE IMPROVEMENT OF THE—

First Period: Historical, and from the Nineteenth Century to 1914—Bauhin, 1550-1624 (Pinax theatri Botanici Basel, 1623), is one of the first authors who wrote on the beet in a comparatively modern way; he gave a good description of the wild forms, and must also be credited with dividing the different beets into distinct species.

The oldest mention of sugar in the beet is made by Olivier de Serres in 1605. Marggraf, in 1747, in a communication to the Academy of Science in Berlin, stated that the beet sugar could be considered as good as cane sugar. He studied the sugar carefully, and gave the first scientific proof that not only simple syrup but a crystallizable sugar could be made out of the beet, and gave very full details of the best ways of purifying it and obtaining a manufactured product. Philippe Victoire de Vilmorin introduced the Silesian beet into France in 1775. The sugar contents of the root at that time were no more than 1·6 per cent.

The cultivation of the forage beet (mangold), potato, and alfalfa was then considered as "new branches of agriculture" in Northern Germany (Lippman in his interesting "Geschichte der Rübe als Kulturpflanze," Springer, Berlin, 1925), and Hauptleutner, in Muhlräditz, used to cultivate the beet root, extract the juice, cook it, and make a syrup for domestic use.

A yellow and very heavy yielding variety (but a kind of salad beet) was also used in southern France a century ago; it did not yield crystallizable sugar, but was used to make a sort of syrup or jam. Its name was "betterave jaune de Castelnaudary."

It is not until the end of the eighteenth century that we get, with Achard, who is considered the raiser of sugar-beet, a real improvement of the plant. Of course, the wild beet, *Beta vulgaris* (or *Beta maritima*), is not devoid of sugar content (Jacques de Vilmorin, "L'Hérédité chez la betterave cultivée," Gauthier-Villars, Paris, 1923). The writer has found wild plants with 14·6 per cent. of sugar, and Saillard found a wild plant as rich as 19·6 per cent. The merit of Achard is great because in his experiments in Caulsdorff and Französisch Buchholtz in Germany he began with a material which was very poor in sugar, and a "population" of types, defying description, from which he made judicious choices.

The first sugar factory was founded by Achard at Cunern in 1802, and another by Achard and Koppy in Krayn.

In these factories different seeds were sorted; the white tap-rooted form was adopted after some time, and is universally in use now.

Achard was also a very good farmer, and gave much information on how to grow sugar-beet. He insisted on deep ploughing, which is a most important preparation of the soil in order to obtain long

SUGAR-BEET (*Continued*)—

and heavy roots. He maintained that such roots cannot grow in insufficiently well and deeply tilled soil, where the elements of the soil and subsoil are not physically reduced to small dimensions, conditions which prove absolutely necessary and require a very elaborate work before sowing. These conditions must be very carefully kept in mind, especially in England, where the beet crop is a new culture.

Achard, in his work, " Anleitung zum Anbau der zur Zuckerfabrikation anwendbaren Runkelrüben," mentions two sorts of beet that he used: one white, giving the best and purest sugar, and the other pink, but deep-rooted. The white variety only is now used for the sugar industry.

Achard maintained that the practice (followed in his time) of removing a part of the foliage while the crop was growing was a very bad one, for it naturally reduced the tonnage, and the sugar content. He wrote his important work, " Die Europaische Zuckerfabrikation aus Runkelrüben," in 1809.

The economic war waged by Napoleon against England, resulting in the boycott of cane-sugar for the Continent, was a great stimulus to the sugar-beet industry, and made it profitable to build sugar factories on the Continent, especially in France.

Delessert, a chemist, was personally rewarded by Napoleon with the Legion of Honour because he established a method for extracting an excellent quality of sugar from the sugar-beet. The Emperor ordered by decree that 32,000 hectares (80,000 acres) annually should be devoted to the sugar-beet crop. Excepting a few districts in the centre and south, it was mainly in the northern districts of France, however, that the cultivation of sugar-beet proved a success.

Mathieu de Dombasle wrote a complete thesis on the subject: "Faits et observations sur la fabrication du sucre de betterave," Paris, 1820. He mentions the exaggerated enthusiasm of the first sugar-beet manufacturers, and shows that some of them made such excellent technical progress, that M. de Koppy, coming to France with the German army in 1815, was astonished at the beauty of the white crystallized sugar he saw at M. de Dombasle's factory. This author describes also the varieties he used (p. 39), and makes interesting remarks on the soils suitable for the sugar-beet in eastern France.

From 1818 to 1831 the rate of progress of the sugar-beet industry slackened in Germany, but in France the very best manufacturers persevered with their factories, and continued to grow beet and sell sugar at low prices. Dubrunfaut, in the introduction of his work, " L'Art de fabriquer le sucre de betteraves," Paris, 1825, gives a very good description of the creditable work of these manufacturers, their determination, their good management, and the improvements they made in their industry. According to this writer there were one hundred factories in France in 1825. He emphasizes the necessity of growing beets with a high percentage of sugar (the farmers generally preferring heavy but poor roots), and gives valuable instructions on best methods of cultivation.

SUGAR-BEET (*Continued*)—

In 1828 the sugar extracted from the beet contributed one-fifteenth of the total French consumption.

From 1831 onwards the industry began to grow again in Germany, largely owing to the progress made in improving the plant in France, and to the adoption of French factory methods. But in addition cereals were very cheap at that time, and in the region of Magdeburg (Germany) especially, where the soil is very suitable for sugar-beet, the landowners were anxious to try some other crop.

Plant selection was greatly helped from 1835 onwards by the invention of the "Rotatomètre" of M. Biot in France, and by the "Saccharimètre Soleil," in the same country, in 1846 (Saillard, "Les graines de betterave à sucre," *Annales de la Science agronomique*, Mai, 1922). These apparatus proved a great assistance in determining the sugar content of the root.

The period round 1840 was characterized by the struggle between the beet-sugar and the cane-sugar produced in the French colonies. Happily for the metropolitan agriculture, the antagonistic parties came to terms, and the sugar-beet industry continued to progress.

In 1850 Louis de Vilmorin produced his improved sugar-beet. The plants were very rich in sugar, and raised by his method of individual selection. For the sugar-beet, as for other plants, he used the progeny of single plants, and after comparison between each separate progeny he chose the best. The desirable characters of the sugar-beet being mostly recessive, he succeeded in raising the percentage of sugar by several degrees—a notable achievement. The plants were named "Vilmorin's Improved Sugar-Beet." The form of the first roots was not perfect (Jacques de Vilmorin, *loc. cit.*), but the new types he obtained very soon after 1850 gave a regular tap-rooted plant.

L. de Vilmorin's selections were obtained from individual roots. Knauer in Germany, at about the same time (1860), raised the Imperial sugar-beet, but used to cross two plants together.

Louis de Vilmorin began by selecting roots on the basis of density; the method used was to take a small cylinder of flesh off the root and test its density in sweetened, and afterwards in salt solutions of different concentrations; both these methods had drawbacks. Before 1850 the Germans also tested the sugar-beet density in salted solutions; in this case they immersed the whole root.

After 1852 de Vilmorin determined the density by means of a silver ingot, and in 1853 he mentions analyses made by himself with the Rotatomètre Biot and Saccharimètre Soleil.

He published the results of his important work at the Académie des Sciences in 1856.

The difficulties arising in France from the competition between metropolitan and colonial sugar were not felt in Germany, which produced only beet-sugar. There the tax for the State was raised on every ton of sugar-beet entering the factory; thus the manufacturer had a very material interest in endeavouring to secure roots rich in sugar.

N. Basset writes in 1874 ("Guide pratique du fabricant de sucre," Librairie du dictionnaire des arts et manufactures) that the French

SUGAR-BEET (*Continued*)—

farmers in his time preferred to grow very heavy roots moderately rich in sugar; and this because the French manufacturers were not in the habit at that time of paying an extra price for very rich roots. There is, in fact, a certain antipathy between weight and sugar percentage: the white mangold (betterave blanche ½ sucrière) has a poor sugar content, yielding no more than 4 to 6 per cent. of sugar and impure juice, impossible to use in sugar factories, but it produces crops of 40 tons per acre. The distillery beet, a richer one, used in the manufacture of alcohol, yields 20 to 24 tons per acre. The heavy sugar-beet, which is not very rich, a little green-topped, like some Schreiber and Branicka types, yields about 16 tons per acre, and the richest, Rabbetghe, Janash, and Vilmorin, only 12 to 14 tons per acre as an average.

Basset draws attention (p. 336) to the anatomy of the root and the presence of circular vascular regions which are more compact and richer than the loose cellular regions between them. It is a good macroscopic way of recognizing sugar texture in beet roots.

Wallkhoff in 1874, in "Traité complet de fabrication et raffinage du sucre de betteraves" (French edition), Paris, Savy, 1874, p. 108, presents numerous ideas on sugar-beet and the sugar-beet industry, and the requirements of the plants regarding temperature.

He also insists on the necessity of hoeing, a very important practice, and considers that one of the chief reasons for the quality of the German sugar-beets near Magdeburg, and for the purity of the juices therefrom, arises from the fact that the farmers there are accustomed to hoe the sugar-beets four or five times during the first months of their growth.

In 1862, the German firm Rabbetghe and Giesecke began the polarization of the juice, and in 1879 the polarization by the extract of the pulp. Some records show that French seed was imported into Germany by the end of this century, and *vice versa* German seed imported into France, each country taking the best of its neighbour's selections or improvements in sugar-beet culture in order to improve its own production.

About 1886, Fouquier d'Herouel (in France) made a good selection: the root was long, the foliage very smooth. This variety exists as a relic only in trial grounds, because new and richer varieties have been raised, but it is generally immune to most of the European plant diseases. Professor Abiko, of the Hokkaido Experiment Station in Japan, also noted the same relative immunity of this Fouquier d'Herouel variety, and made crossings with it quite recently in the hope of securing new immune varieties.

Darwin, "The Effects of Cross and Self Fertilization in the Vegetable Kingdom," London, 1876, discussed the question of the effects of cross- and self-fertilization in the sugar-beet. He made a comparison between plants raised from an individual plant and from a crossing; the plants obtained from a crossing gave a better crop.

Lippman in the "Geschichte der Rübe (Beta) als Kulturpflanze," Springer, Berlin, 1925, says the tonnage per acre in Germany in the

SUGAR-BEET (*Continued*)—

period 1850-1860 was about 8 tons per acre. It is now about 10 to 12 tons per acre.

The following figures show the advances in sugar content and in yield of sugar per acre during the period 1850-1926:

Years.	*Percentage of Sugar in Roots.*	*Sugar per Acre.*
1850-1860	7·8	1,640 lbs.
1870-1880	8·6	1,970 ,,
1890-1900	13·3	3,530 ,,
1920-1926	16·0	3,530 ,,

In France, the percentage of sugar and the sugar yield per acre did not quite reach the German figures. See Saillard, "Les rendements de la betterave à sucre," *Comptes rendus de l'Académie d'Agriculture*, séance du 18 Décembre, 1929.

In Germany the number of factories and the total production of sugar since 1836 have been:

Years.	*Number of Factories.*	*Total Production of Unrefined Sugar in Tons.*
1836-37	122	1,408
1840-41	145	14,205
1850-51	184	53,349
1860-61	247	126,526
1870-71	304	186,441
1880-81	333	573,030
1890-91	406	1,336,221
1895-96	397	1,637,057
1900-01	395	1,979,118
1905-06	376	2,394,400
1910-11	354	2,589,869
1915-16	320	1,522,636
1921-22	263	1,284,229
1925-26	261	1,584,600
1927-28	250	1,647,344
1928-29	238	1,851,263
1929-30	238	1,965,000

The recent reduction in number of the factories is due to the "rationalization" or process of suppression of the smaller and older factories and the concentration of the industry in the largest and best equipped.

In France we have the figures given on top of p. 1177.

The number of factories fell to 206 before the Great War, as there was then a tendency to suppress the small factories and to concentrate the industry in large ones. At the conclusion of the War, in 1918, the factories existing were no more than fifty-one, many having been destroyed during hostilities. In 1924, they were ninety-six in number. The acreage varied from 112,000 hectares (1 hectare = 2½ acres) in 1885 to 302,000 in 1900; 216,000 hectares in 1913; only 59,000 hectares in 1918, and 149,000 in 1923; the tendency is to reach at present the figure of about 200,000 hectares (500,000 acres).

SUGAR-BEET (*Continued*)—

Years.	*Number of Factories.*	*Total Production of Refined Sugar in Tons.*
1838-39	547	33,000
1840-41	418	23,000
1845-46	306	35,000
1850-51	304	65,000
1855-56	275	79,000
1860-61	334	108,000
1865-66	398	128,000
1870-71	476	248,000
1875-76	525	396,000
1880-81	509	283,000
1884-85	449	273,000
1890-91	377	615,000
1895-96	344	593,000
1900-01	334	1,040,000
1909-10	244	733,901
1915-16	51	135,899
1927-28	108	764,949

In the United States of America the first factory was established in 1888, the number of which increased as follows:

Years.	*Number of Factories.*	*Production of Sugar in Tons.*
1893-94	6	19,550
1898-99	15	32,471
1905-06	53	283,717
1910-11	63	455,220
1915-16	67	779,756
1920-21	97	969,419
1925-26	88	804,439
1927-28	82	965,241
1928-29	84	925,000

The sugar-beet is a relatively new crop in England; the first cultivation began in the eastern counties, and the roots were shipped to the Dutch factories.

The first factories were established at Cantley in 1912, and at Kelham in 1920. The development of the industry has been rapid: nine factories were in operation in 1926, fourteen in 1927, and nineteen in 1929-30. The sugar extracted was:

Years.	*Tons.*	*Years.*	*Tons.*
1922-23 ..	.. 7,011	1926-27 ..	.. 153,296
1924-25 ..	.. 23,886	1929-30 ..	.. 281,500 (estimated)
1925-26 ..	.. 51,754		

The sugar-beet industry is very important in Czechoslovakia, the State having interested itself to the extent of building and maintaining a very important establishment in Prag devoted entirely to the study of the plant and the improvement of the sugar industry. Among other countries, Poland obtains excellent and very rich roots. Russia—a great producer before the War—is now endeavouring to develop its industry again. Russian experts carry out research work along biological

SUGAR-BEET (*Continued*)—

and experimental lines (see, amongst others, Orlowsky, "Beiträge zur Untersuchung einiger zuckerreichen Sorten der Zuckerrübe," Kief, 1928).

In Sweden, the whole industry is under the management of a general syndicate. Belgium and Holland have very good sugar factories, and Switzerland only one.

Italy possesses a large industry in the north, the Genoan people having played a prominent part in its foundation. Spain has also a sugar-beet industry, mostly on irrigated fields; it is interesting to note that cane-sugar is grown in the south (Malaga).

The European production of 1926-27 in countries other than those of which the figures have been given previously was as follows (the German, French, British, and United States results have been summarized in the previous pages):

Czechoslovakia	1,657,000 tons.
Belgium	233,000
Holland	287,000
Russia and Ukrain	871,000
Poland	552,000
Denmark	151,000
Italy	313,000
Spain..	284,000
Rumania	162,000

The following countries, Austria, Sweden, Switzerland, Bulgaria, and some others, do not reach a production of 100,000 tons each; the total European yield being 6,871,892 tons per annum.

The world's production for the year 1926-27 was (in tons):

Cane-Sugar.	*European Beet-Sugar.*	*American Beet-Sugar.*		*Total.*
		U.S.A.	*Canadian.*	
16,028,612	6,871,892	801,246	31,422	23,733,172

Second Period, 1914-1930: *Recent Problems*—The new methods of selection consist in putting the mother beets under canvas in order to obtain self-pollination, the plant being naturally cross-pollinated. The progeny of each single self-pollinated beet is cultivated separately, and when proved good it is recrossed to avoid the debilitation which accompanies auto-fertilization.

These methods were adopted by Professor Munerati in Italy, and the writer in France at about the same time. Some raisers, in Sweden, isolate a single branch of the mother beet under canvas or a parchment paper bag.

The experiments of Professor Munerati have been very important in this and in all questious appertaining to the sugar-beet. He published his excellent work, "Osservazioni e ricerche sulla barbabietola da zucchero" (Roma, Academia dei Lincei), in 1920, and has made an important number of publications since then.

Tjebbes, "Gjalvbefrukkning och inavel hos Beta" (Kongress in

SUGAR-BEET (*Continued*)—

Oslo, Juni, 1926), has an original way of selecting by inbreeding, which differs from the methods of isolation under canvas.

The character "very high sugar content" is happily fairly constant: three groups of very rich strains observed by Urban ("Hoch polarisierende Rübe und ihre Nachkommenschaft Zeit," *Zucker. Ind.*, Böhmen, 1919) did not vary in richness during the three succeeding generations.

The problem of producing crops with non-bolting roots is very important. To obviate this trouble sowing must not be too early because the beet is not fixed as a biennial plant, and any serious check in the vegetation has the result of hardening the tissues, and the plant "bolts" afterwards in the same year. Seed growers are actively engaged in producing types of non-bolting plants.

Sir D. Hall, "Bateson's Experiments on Bolting in Sugar Beet and Mangolds," *J. Genetics*, November, 1928, shows that there is always a small percentage of plants bolting the first year, the biennial character of the plant not being an absolutely fixed character yet, a fact also mentioned in "L'Hérédité chez la betterave cultivée," *loc. cit.* Sir Daniel Hall points to the fact that very early sowings (in December), which means the very worst conditions for the development of the plant, reveal the tendency of the plants to bolt, very few exhibiting non-bolting habit. This system has been tried by M. de Vilmorin, who from early sowings discards every plant showing a tendency to bolt.

Dudok van Heel, "Inheritance of Bolting in Sugar Beet," *Genetica*, 1927, shows that the bolting character is recessive.

Most of the valuable economic characters of the sugar-beet are also recessive, with the exception of the anomaly of the rugose skin, the smooth skin in this case being dominant. It is easy to see if a mangold has been hybridized by a sugar-beet, for the characteristic foliage of the sugar-beet, with deep-rooted pivots, is easy to identify. In the case of a partial hybridization of sugar-beet by white mangolds, the way to scrutinize is to cut the root and to look at the internal structure, which is far less dense in the mangold than in the sugar-beet; this first examination has to be confirmed by the study of the richness in the laboratory (Pack, "Ring Density of Sugar Beet as a Character for Selection," *Am. J. Bot.*, xiv., 238-245, 1927).

The Cercospora Disease (*Cercospora beticola*) has been studied recently, and special treatments made, principally in Italy. In that country the plant ripens as early as August, except on the high plateaux. Professor Munerati, the Head of the special official station for beet culture in Rovigo, has made numerous crossings with the wild beet in order to obtain plants with a stronger and more drought-resistant foliage.

In America the greatest trouble is the Curly Top, a special American disease whose origin is not yet ascertained, although one knows the infection is produced by a Virus, and results in destruction of wide areas of sugar-beet culture (see Virus Diseases, and ditto under Potato, Tomato, Hop, Raspberry, etc.). The Government and private agricultural experts are busily searching for disease-resistant strains (see

SUGAR-BEET (*Continued*)—

"Curly Top: A Disease of the Sugar Beet," Washington Government Preventory Office, 1908; "Resistance in Sugar Beets to Curly Top," Eubanks Carsner, Washington Department Circular No. 388, 1926).

The total income of the sugar-beet-growing farms on the Continent has increased in a very marked way when compared with farms on which sugar-beet is not grown: first by the sale of the sugar plant itself, and then as a result of better yields of cereals in succeeding years attributable to the deep ploughing, and finally by feeding the sugar-beet pulp to cattle. Some farms increased their cattle population by 40 per cent. as a result of the sugar-beet crop (see also on this subject and for general information the excellent book of Dr. Theodor Roemer, "Handbuch des Zuckerrubenbaues," Berlin, Paul Parey, 1927).

Farm implements have been very greatly improved as a result of the necessity of cultivating with more perfection, for the root will only give the best results on well-tilled, manured, and managed soils. The testimony of this betterment can be found in a very abundant literature, the best communication made on the subject being by Saillard, *Comptes rendus de l'Académie d'Agriculture de France*, Décembre 18, 1929.

J. de V.

SUGAR-BEET, INSECT PESTS OF—The sugar-beet in the British Isles is liable to attack by about a dozen insects of different kinds, including aphides, beetles, and flies. Of these insects not more than five or six commonly attack the sugar-beet, the others being more potential than actual pests, and all are equally liable to attack the mangold as well as the sugar-beet. In the ensuing article the most important of these insects will be dealt with in turn, and a short description given, together with an account of the damage caused to the beet, and the best methods of control. (See Insecticides and Fungicides.)

The first insect, then, belongs to a primitive group known as *Collembola*, or Springtails, so called because of the jumping apparatus at the end of the abdomen. The particular insect in question is *Bourletiella hortensis* Fitch., sometimes called the "Garden Springtail"; it is very small, measuring 1·2 to 1·5 mm. in length. The body is globular and the colour blackish to dull green above, usually marked with white spots. It is a jumping insect, progressing by the aid of the "springtail" from which it takes its name. *B. hortensis* is primarily a pest of mangolds, but often attacks sugar-beet also, as do many of the insect pests of mangolds. The damage done by this Springtail is confined mainly to the seedling plant, and attacks may be on both stem and leaves. In the former case the stem is eaten round at, or just above, ground level, giving rise to a constriction. Young plants affected with this constriction are very liable to be broken off by the wind; in the second form of damage, the cotyledons are eaten off and the seedlings consequently killed. During the past four years (1927-30) attacks of this insect on sugar-beet have been recorded from Morpeth, North Shropshire, Durham, and Lincolnshire.

SUGAR-BEET (*Continued*)—

Control.—Control measures consist of the application of a 5 per cent. nicotine sulphate dust or fine air-slaked lime; these dusts must be applied in the evening or early morning, or on occasions when the humidity is high. W. M. Davis ("*Collembola* injuring the Leaves of Mangold Seedlings," *Bull. Entom. Res.*, xvii., 1926-27) has shown that large numbers of *Collembola* may be caught on tarred sacks stretched across a light wooden frame mounted on wheels, and pushed by the operator along the rows.

The next insects to be considered belong to the group *Hemiptera*, which includes Plant Bugs and Plant Lice; all these are sucking insects, and feed upon the plant sap which they draw up into the body by means of the proboscis or beak; they do not eat the leaf tissue itself. This class of insect is the one chiefly concerned with the spread of "Virus Diseases" of plants, several of which affect the sugar-beet (see Virus Diseases of Sugar-Beet.) There are two types of Hemipterous insects which attack sugar-beet—the Capsid Bugs and the Aphides or Green Flies. Of the Capsid Bugs two species are dealt with: these are *Lygus pabulinus*, the Common Green Capsid Bug (see F. R. Petherbridge and W. H. Thorpe, "The Common Green Capsid Bug," *Anns. Appl. Biol.*, xv., No. 3, 1928); and *Orthotylus marginalis*. The Common Green Capsid measures about 6 mm. long when fully grown; it is winged in the adult stage, but the young forms are wingless; it is equally injurious in all its stages. The chief damage to the plant is due to a poison contained in the salivary secretions of the insect which are pumped into the plant, causing the leaves to become distorted and inhibiting growth.

The damage is most severe on the seedlings, the stems and cotyledons being punctured, but sometimes the attack is confined to the young leaf growth. Recent damage to sugar-beet by this Capsid has been reported from Lindsey and central Somerset. The attack is usually confined to the edges of the field and near headlands; this is due to the migration of the Capsid Bugs from their winter quarters in the hedgerows. As a control for this bug the application of some insecticidal dust containing nicotine is recommended (see C. L. Walton and L. N. Staniland, "The Common Green Capsid Bug as a Pest of Sugar-Beet," *Ann. Rept. Long Ashton Expt. Stat.*, 1929). The other capsid bug (*Orthotylus marginalis*) is only an occasional pest of sugar-beet, and as such is briefly mentioned; when recorded the insects have probably migrated to the beet from a neighbouring orchard.

Of the Aphides or Green Fly, there is one species which is of importance, and is sometimes a serious pest; this is *Aphis rumicis*, and is the same insect as that which attacks broad beans; it is usually known as the "Bean Aphis" or "Black Fly." The wingless female of *A. rumicis* is dull black with paler legs and antennæ, the young are deep green, and the nymphs which show wing buds are often slightly mealy. The winged female appears dark to almost black, but the body is really deep green with black bars (see F. V. Theobald, "Aphides attacking Vegetables and Market Garden Crops," *J. Roy. Hort. Soc.*, L., part i., 1925). The chief importance of *A. rumicis* to sugar-beet

SUGAR-BEET (*Continued*)—

lies in the fact that it has been proved to be a vector of the Virus Disease of this plant known as "Mosaic" (see Virus Diseases of the Sugar-Beet). The nicotine dust recommended for the Green Capsid Bug would probably also be efficacious against *A. rumicis.* The Spinach Aphis (*Myzus persicæ*) is sometimes a pest of sugar-beet, and this insect also transmits the virus of sugar-beet mosaic. A third aphis which occasionally attacks sugar-beet is the so-called "Boat-Gall Aphis" (*Hyalopterus atriplicis* L.). This aphis forms curious boat-shaped galls on the leaves of chenopodiaceous plants, but is seldom a serious pest.

There are several beetles (*Coleoptera*) which are injurious to the sugar-beet. The first and most important of these is the Pigmy Mangold Beetle (*Atomaria linearis*); this is a very small insect, less than 2 mm. in length. The colour is variable from deep red to black, the antennæ are brown with the three apical segments dilated, and the legs are reddish-brown. The beetle passes the winter under clods of earth or débris in fields and meadows. In May or June these hibernating individuals appear and attack young mangolds and sugar-beet seedlings just below ground level; seedlings so attacked often die or are broken off by the wind. The injury caused by this beetle is similar to that due to the Springtail (*B. hortensis*), except that damage by the latter is above the ground level. *Atomaria linearis* is probably the worst insect pest of sugar-beet, both in the British Isles and on the Continent. Attacks on sugar-beet by this insect appear to be largely governed by the nature of the preceding crop, and therefore attention to a suitable crop rotation is one of the means of combating the pest. It has been found that attacks are always worst when the sugar-beet follows beet or mangolds; there are records of 2½ acres of sugar-beet following mangolds being completely destroyed by this beetle, while sugar-beet in the same vicinity which followed potatoes and swedes was not attacked.

Control.—Heavy rolling with a Cambridgeshire roller has been found beneficial; chemical treatment of the soil is not considered feasible owing to the difficulty of penetrating deeply enough. In the sugar-beet fields on the Continent trapping is practised; holes are dug in the soil about 16 ins. wide and deep, and filled with beet leaves and stems. Sowing crude naphthalene with the seed at the rate of 1 part by weight to 20 parts of beet seeds is also practised as a deterrent.

The next beetle to be considered is the Small Green Tortoise Beetle (*Cassida vittata* Vill.); this, as its name implies, is a small green insect with a flattened shield-like appearance. *C. vittata* is not often a serious pest of sugar-beet in Britain, but may become one in the future. The insect appears in April and May, and lays its eggs on the leaves of mangolds and sugar-beet. In case of a bad attack, the control measure advised is to spray with 1 per cent. colloidal lead arsenate as soon as the beetles appear, the spray being repeated two or three times while the leaves are still growing vertically (see C. Menozzi, "Insetti dannosi alla barbabietola osservati durante la campagna, 1929," *Indust. saccarif. ital.*, xxiii., 1, 2, and 4, Genoa, 1930).

SUGAR-BEET (*Continued*)—

Among the so-called "Flea Beetles" which attack a variety of agricultural crops is one species, the Mangold Flea Beetle (*Plectroscelis concinna* Marsh.), which is occasionally a pest of sugar-beet. It is a small oval, shining insect of a metallic bronze colour, about 2 mm. in length; the legs are reddish with the shanks of the posterior pair greatly dilated. It can be distinguished from other Flea Beetles by the tooth-like projections on the hind legs. The adult beetle eats round holes in the seedling leaves; it sometimes appears in combination with the springtail (*B. hortensis*), and the two together may do serious damage.

Control.—Control measures consist in sowing deterrent dusts with the seed, or steeping the seed with turpentine before sowing. Against the spring attack on seedling plants, thorough hoeing between the rows is important, as the growth of the plants is thereby encouraged and the flea beetles are disturbed. Of deterrent dusts and sprays, nicotine sulphate is probably the best; as a dust it should be used with a 3 per cent. nicotine content with an inert lime basis, and as a spray with 0·2 per cent. of nicotine (see H. C. F. Newton, "Observations on the Biology of some Flea Beetles of Economic Importance," *J.S.E. Agric. Coll., Wye,* Kent, No. 26, 1929).

A fourth species of beetle is occasionally destructive to sugar-beet in England; this is one of the so-called Carrion Beetles, the Beet Carrion Beetle, *Blitophaga opaca* Linn. The insect has adopted the phytophagous habit, and has developed into a serious pest of the sugar-beet in Germany, where it has been calculated that the progeny of one pair of beetles is capable of defoliating 100 square yards of cultivated land. The adult insect is oval, rather flattened, and clothed with dark orange to reddish hairs which give it a bronze tint; it measures about 10 mm. in length. The winter is spent by the adult beetles under stones or moss, whence they appear in May or early June and migrate to young beet and mangold plants. The eggs are deposited in the soil; after five to nine days the larvæ hatch and make their way to the young leaves, where they feed for about three weeks. Both adults and larvæ feed upon the leaves, the attack beginning at the edges, which frequently turn black; later the larvæ may turn their attention to the roots, which they eat through just below ground level.

Control.—Control measures consist in frequent hoeing to disturb the pupæ and also the eggs, which are very susceptible to drought. The following sprays may be used when necessary: Paris green at the rate of 3 to 4 lbs. per 100 gallons of water, to which has been added 3 to 4 lbs. of chalk and $\frac{1}{5}$ lb. of gelatine to make it adhesive; or, alternatively, 50 lbs. barium chloride and 20 lbs. wheat flour to 100 gallons of water.

Turning now to another group of insects, the true flies or *Diptera*, the larvæ of two species are found to be of importance. The first of these is the Beet or Mangold Fly (*Pegomyia hyoscyami*, var. *betæ* Curt.). This insect is about the size of a house fly, which it somewhat resembles. It may be of a reddish tint, but the colour varies according to the food plant of the maggot; it measures 5 to 6 mm. in length. There are

SUGAR-BEET (*Continued*)—

usually three broods of this fly in the year, the winter being spent as a chrysalis in the ground a few inches below soil level. The fly emerges in April, and the female deposits her eggs on the under surface of beet and mangold leaves, usually in batches and often in parallel rows. Attacks first develop from about the middle of May to early in June. The eggs hatch in a few days, and the whitish maggots feed in the soft parenchymatous tissue of the leaves, in which they raise large blisters (see A. E. Cameron, "Life History of *Pygomyia hyoscyami*," *Anns. Appl. Biol.*, i., No. 1, 1914). It is the first generation of larvæ attacking the young seedling plants which is of most importance, the leaf area being so reduced that the young plants are unable to withstand the attack.

Control.—As control measures, spraying the seedling plants with paraffin emulsion (1 pint paraffin, 1 lb. soft soap to 10 gallons water), or nicotine sulphate (2½ ozs. nicotine sulphate, 1 lb. soft soap, 10 gallons water) are recommended (see C. L. Walton, "Some Experiments for the Control of Mangold Fly," *Welsh J. Agric.*, 1928). Stimulating dressings, early sowings, and careful cultivation are helpful. A poison bait to kill the adult flies before they lay their eggs is sometimes recommended; this consists of 176 lbs. of chaff mixed with 9 to 10 gallons of a solution containing 2·5 per cent. of sugar and 4 per cent. of sodium fluosilicate, these being the quantities per acre. A little horse dung is added to attract the flies, and the bait should be placed about the field in heaps of about 5 lbs. each (see R. Schander and G. Gotze, "Erfahrungen über das Auftreten und die Bekämpfung der Rübenfliege im Jahre 1928," *Forsch. Landw.*, iv., No. 6, 1929). The second type of fly larva which is sometimes injurious to sugar-beet is the so called "Leather-Jacket" or "bot," which is the young form of the well-known Crane Fly or Daddy-Long-Legs (*Tipula* spp.). These larvæ attack a very wide range of agricultural crops, and cannot be considered as a special pest of sugar-beet. In appearance the Leather-Jacket is a greyish-brown maggot, legless, and without a well-defined head; it has a tough outer skin, from which it takes its popular name. These larvæ live in the soil just below the surface, and feed upon the root and underground portions of the stem. The usual method of control for Leather-Jackets is the use of the poison bait; this consists of Paris green, bran and treacle made up in the following proportions and broadcast over the field so that it is evenly and thinly distributed: Paris green 1 lb., bran 20 lbs., water 1 gallon, molasses or treacle ½ pint; this quantity is sufficient for 1 acre.

As regards many of the foregoing insects, which are mainly associated with the Chenopodiaceæ, the weeds belonging to the same group may play a part in the spread of such insects. On the Continent wild species of *Atriplex*, for example, are regarded as a source of special danger to the sugar-beet crop, owing to the transfer of insect species from this weed to the beet.

VIRUS DISEASES OF THE SUGAR-BEET—Owing to the close connexion of the so-called "Virus Diseases" of the sugar-beet—and of

SUGAR-BEET (*Continued*)—

plants generally—with insects, it is convenient to treat of these disorders in close connexion with the article dealing with the insect pests of the crop. As plant Virus Diseases are almost entirely dependent upon insects for their spread in the field from diseased to healthy plants, the problem becomes largely an entomological one.

There are three Viruses, so far known, which affect the sugar-beet and allied plants; two of these occur in Europe, and one, at present, only in North and South America. The first two are Mosaic and Leaf Crinkle, while the third is known as Curly Top. It will be noticed that these diseases are named after the attendant leaf symptoms; this is the usual method of nomenclature in plant Virus Diseases, the existence of which can only be recognized by the pathological symptoms they cause. Curly Top of sugar-beet, which only occurs in North and South America, is a very serious disease; the symptoms take the form of a transparent network of minute veins, generally on the youngest leaves, while small blister-like elevations on the leaves are sometimes shown. Another constant symptom is the presence on the lower surface of the leaves of numerous wart-like protuberances (see H. H. P. Severin, *Calif. Agric. Expt. Sta. Bull.* 465, 1929). This virus is spread from diseased to healthy plants by the agency of a small insect known as a Leaf Hopper, *Eutettix tenellus* (see E. Carsner and C. F. Stahl, " Studies on Curly-top Disease of the Sugar-Beet," *J. Agric. Res.*, xxviii., No. 4, 1924), and by no other insect in North America, though another leaf hopper, *Agallia sticticollis*, seems to be the vector in the Argentine (G. L. Fawcett, " The Curly Top of Sugar-Beet in the Argentine," *Phytopath.*, xvii., 6, 1927).

Of the two European virus diseases affecting sugar-beet, one of these, Mosaic, occurs in England as well as on the Continent and in the United States. The symptoms of Mosaic are a spotting of the leaves, together with some malformation such as curling of the leaf margins. The spots differ in size and character; they are most often almost circular, sharply delimited lesions of small size and varying colours, composed of several yellowish-green zones radiating from a dark green centre (see K. Böning, *Forsch. auf dem Gebiet der Pflanzenkrankh. u. der Immunität. im Pflanzenreich*, iii., 1927). There are probably at least two insect vectors which transmit Sugar-Beet Mosaic from diseased to healthy plants. These are two species of Aphides or Green Fly, already mentioned in connexion with the insect pests of sugar-beet, *i.e.*, *Aphis rumicis*, the Black Bean Aphis, and *Myzus persicæ*, the Spinach Aphis (see W. W. Robbins, " Mosaic Disease of Sugar-Beet," *Phytopath.*, xi., 9, 1921). When the infective insect has fed upon a healthy sugar-beet plant, symptoms of Mosaic commence to develop in that plant after ten to twenty-four days. As with most plant Virus Diseases, infection does not appear to be transmitted through the seed. Sugar-beet Mosaic is probably also infectious to mangolds and spinach, and infection may be disseminated from one crop to another by the same two aphides, and possibly also from infected chenopodiaceous weeds.

The disease has been recorded in England from Nottinghamshire

SUGAR-BEET (*Continued*)—

and Lincolnshire, and is apparently rather prevalent in the East Midlands. There does not appear to be much difference in the susceptibility of different kinds of sugar-beet to the Mosaic Virus; Böning (*op. cit.*) has tested twenty-two varieties, but all were susceptible to the disease.

The control of the aphides which transmit Mosaic is a difficult matter, but probably a nicotine spray or the nicotine dust recommended for use against the Common Green Capsid Bug would materially reduce their numbers.

The third Virus Disease of the sugar-beet mentioned is Leaf Crinkle or "Krausel Krankheit," and this has not up to the present appeared in the British Isles. Owing, however, to its rapid spread in Germany, where it has become a serious menace to the industry in certain parts, and to the fact that the insect vector is indigenous to this country, it may be well to give a short account of it as a potential pest of sugar-beet in the British Isles. The symptoms of the German Leaf Crinkle somewhat resemble those of the American virus of Curly Top, but the two viruses are apparently distinct. The symptoms, which appear twenty-one to sixty-five days after infection, consist of a swelling, crookedness, and glassiness of the leaf veins and petioles, crinkling due to inflation of the leaf parenchyma, arrest of growth, and dying of the older leaves. The insect vector is a plant bug, *Zosmenus* (*Piesma*) *quadrata* Fieb.; no other insect is known to be a vector at present (see Joh. Wille, "Die Rubenblattwanze, *Piesma quadrata*, Fieb.," *Monographien zum Pflanzenschutz*, 2, Berlin, 1929). As already mentioned, *Z. quadrata* occurs in the British Isles, and is described by Saunders ("The Hemiptera-Heteroptera of the British Islands," p. 121, 1892). It is a dull greyish insect, oval in shape, and with a spine in front of each eye; the basal joint of the antennæ is very thick, and the legs are yellowish; it measures between 2 to 3 mm. in length. It is common in many places generally near the coast, on wild *Chenopodium* spp. and other plants, especially in salt marshes.

There seems to be a tendency among plant bugs of this type to forsake their wild host plants and frequent cultivated crops of the same or allied natural order. *Z. quadrata* began to attack sugar-beet in Germany about the beginning of this century, and its adoption of this new host was followed by the appearance of the Leaf-Crinkle Disease. In England a somewhat similar state of affairs is shown in the case of the Green Capsid Bug, *L. pabulinus*, which is forsaking the weeds upon which it used to feed, and is attacking many important cultivated crops, of which the sugar-beet appears to be one.

The control method adopted in Germany against *Z. quadrata* is to plant a catch-strip of sugar-beet round the fields about two weeks before the main crop is sown. This catch-strip, developing a fortnight before the main crop is beginning to appear, is invaded by *Z. quadrata* which has survived the winter, and at the time the main crop is beginning to show above ground the strip is disinfected and then buried deeply in the soil.

K. M. S.

SUGAR-CANE—That essential commodity of civilization, sugar, is derived mainly from two sources, the sugar-cane and the sugar-beet (*q.v.*). The former is a tropical and subtropical gramineous plant, the origin of which, like that of most plants which have been cultivated throughout the centuries and carried round the world, is obscure. There is, however, solid reason for supposing a dual origin. One group, the typical *Saccharum officinarum* L., the so-called "Noble" canes, appears to have been derived from Oceania; the other from India. The cultivated canes of this latter group have been classified under *S. officinarum*, but, as Barber has shown (*Mem. Dep. Agric. India*, vii., 1915; viii., 1916; ix., 1918), the canes of this group show undoubted evidences of a dual origin from the wild *Saccharum spontaneum* L. Jeswiet, in a review of the genus, recognizes four species: *S. officinarum* L., *S. spontaneum* L., *S. sinense* Roxb., and *S. Barberi Jeswiet* (*Arch. voor de Suiker Ind.*, xii., 1925).

The cane plant is a perennial grass, and, as such, the aerial stem is divided by nodes into a series of internodes. A leaf arises from each node and carries in its axil a bud. Above the bud, on the stem, lies the "root band," from which adventitious roots may develop, and above this a "growth ring," the cellular tissues of which remain plastic for a longer time than the main tissues of the internode. At the other extremity of the internode, below the succeeding node, lies the "glaucous band," so called from the heavy deposit of wax which, in certain varieties, extends over the whole internode. The inflorescence is a typical loose gramineous panicle known as the "arrow." Propagation is normally vegetative; sets composed of sections of the culm, the aerial shoot, carrying two or more nodes with buds, being placed in the ground. From the root bands of these sets adventitious roots arise, while the buds send up aerial shoots which tiller at the base.

The origin of the earliest varieties of cultivation is not known with certainty, but in recent times the number of varieties has been largely increased. The source of these is twofold. Asexual variation is known to occur, and examples of the isolation of "sports" so arising are on record. Thus the White and Black Tanna canes were isolated in Mauritius from the Striped Tanna. The identification of such sports is, however, limited to cases where some prominent characteristic is involved. The prospect of securing sports where the less obvious economic characters are concerned is dubious, both on account of the difficulty of identification and because the sporting habit appears to follow a definite course, the same sport appearing in any particular variety at irregular intervals. The second method, which has been developed extensively in recent years, is from seed. Though earlier records of seedling canes existed, the matter remained an open question till Soltwedel in 1888, working in Java, and Harrison and Bovell in 1889, working in Barbados, independently established the fact that the cane plant sets viable seed. The economic pressure which led to these discoveries was exerted by epidemics. In Porto Rico, in 1872, the Otaheite cane was attacked by root disease in epidemic form; in the British West Indies the attack took a less virulent form, but led to the replacement of Otaheite by Cheribon cane. In Java, about

SUGAR-CANE (*Continued*)—

1880, "sereh" attacked the Cheribon cane, and about 1915 "mosaic," already known in Java, assumed epidemic proportions in Porto Rico. The discovery of the possibility of raising seedlings offered a promising field from which to obtain varieties resistant to these diseases, and work along these lines was vigorously pursued in Barbados on a mass-production basis. Viable seed was sought without regard to parentage, and the many thousands of seedlings raised were subjected to selection for agricultural suitability of habit, disease resistance, and so on, and for factory suitability of sugar content and percentage of fibre. Lewton-Brain in 1904, working in Barbados, and Mitchell in 1905, in Queensland, were first in the field in securing crosses of known parentage by emasculation and dusting on pollen. In Java the more systematic method was followed, using in the earlier work, with which the name of Kobus is associated, the Indian Chunnee cane as male parent and later Kassoer, a wild Javan cane, on cytological grounds believed to be a natural cross between *S. spontaneum* and the Dark Cheribon. Many of the most successful of the Javan crosses come from this latter cross. Thus No. 2725 of the POJ (Proef-Station Oost-Java) series has a parentage POJ 2364, itself Kassoer × POJ 100, by EK 28, which is POJ 100 × EK 2, in its turn having a parentage Red Fiji × Otaheite. But it was Barber, working at Coimbatore in India, who went directly back to *S. spontaneum* for his parent stock (Deer, *Agric. J. India*, xxv., 2, 1930).

The raising of seedling canes is work now undertaken in most cane-growing countries where the cane, as is not always the case, sets viable seed. The factors which condition the setting of such seed are not clearly understood. One obvious limitation is temperature, for in the subtropical areas where the cane arrows in the cold season viable seed is not obtained. Difficulty also arises, when crosses are to be made, in obtaining synchronous flowering of the different varieties.

The discovery of the possibility of raising viable seed has been of immense economic value in other directions beside the question of disease. The process of sugar extraction from the cane has undergone a revolution in recent times. With the introduction of the vacuum pan, economic sugar production is only successful with large units. The central factory, which is characteristic of modernized production, is such a large unit, the cost of which will run into six figures, and it normally operates only for a portion of the year, the crop season, when the crop is "ripe." Ripening of the cane is the term applied to that process, somewhat indefinite in time, when the sucrose content of the juice approaches the maximum and the glucose content a minimum; it is a seasonal phenomenon associated with dry weather and a check to growth. It is clearly one of the objects, with such a large capital sum involved, to distribute the overhead charges by extending the crop season as far as possible. It is now becoming the practice to plant up areas of supply with canes of differing maturation periods, and a search is continually being made for seedlings which, by possessing an early or late maturing habit, will render a prolongation of the crop season possible.

SUGAR-CANE (*Continued*)—

Agriculturally, there is ample scope for improvement of practice in most cane areas. Yields fall far short of the potential capacity of the land, and a fraction of the energy devoted to recovering 0·1 per cent. of the sucrose in the factory would be well repaid if expended on increasing the yield. The factory unit is now so large that difficulties are often experienced in securing an adequate cane supply, and it is too little realized that increased yield is an alternative to increased area in producing that supply. Though in some cases, of which Java and Northern India are examples, cane yields a single crop, the commoner practice is to obtain a succession of crops by ratooning. In the former case, the plant occupies the ground for eighteen months; in the latter, some nine to twelve months. In the former case it is a definite land policy which dictates the practice; in the latter it is the necessity for fitting the crop into a somewhat complex rotational system on peasant holdings. Where ratooning is practised, only a fraction of the area is planted up each year to yield "plant cane," and subsequently a ratoon crop is obtained from the stools left in the ground. The process may be repeated two to five times (commonly) and even indefinitely (British Guiana). The exact number of ratoon crops is a matter for economic determination, the extra cost of planting up balanced against the diminishing return, for normally the heaviest yield is obtained from plant cane or first ratoons, subsequent crops gradually diminishing in weight. This is a purely local problem, but one for which the answer is not necessarily easily computed; for other factors, such as the necessity for securing a full supply of cane for the efficient running of the factory, enter into the calculation. But the practice raises an agricultural problem which may be defined as one of maintaining the necessary tilth for healthy growth while the crop occupies the ground, and prevents the direct adoption of the normal agricultural operations of a fallow.

The tropical conditions under which cane normally grows—a relatively high temperature accompanied by high rainfall—are such as tend to a rapid destruction of humus, with an acidic and anaerobic tendency in the soil which renders the somewhat heavy lands on which cane is normally grown liable to become intractable. These, too, are the conditions which lead to an unhealthy physiological condition of the plant. Restoration of humus and an improvement of tilth are the objectives to be aimed at. The common practices after cutting of leaving trash, the stripped leaves, on the field, of raking the trash on to alternate lines and intercultivating the alternate exposed strips, with a reversal of the process in the succeeding year, are steps in this direction. The question of humus, apart from tilth improvement, is bound up with the question of the nitrogen requirement of the plant (Clarke, *Agric. J. India*, xxv., 2, 1930). In this matter of adaptablity to unfavourable soil conditions too little attention has been given to the question of root formation. A study of root development has been made by Venkatraman at Coimbatore (*Mem. Dept. Agric. India, Bot. Ser.*, xiv., 3, 1927). There is here further scope for the economic employment of the power to raise seedling canes.

SUGAR-CANE (*Continued*)—

It is only where cane is grown out of the tropics or at high altitudes that temperature becomes a limiting factor in cultivation. In Mauritius, cane at sea level matures in thirteen months, and at 1,100 ft. in twenty-one months (Walter, "The Sugar Industry of Mauritius"). In most cane countries water is the limiting factor, and below some 50 ins. per annum the natural rainfall requires to be supplemented by irrigation. Numerous estimates of the water requirement for a crop of cane have been made. Maxwell, in Hawaii, estimates that young cane requires 0·5 in. per week; later, up to the third or fourth month, 1·0 in., and subsequently 1·5 ins. (*U.S. Dept. of Agric., Office of Exp. Sta. Bull.*, 90). But distribution is as important as total quantity, and it is not often possible, as Rawson attempted in Barbados (Rawson, "Report on the Rainfall of Barbados and its Influence on the Sugar Crop, 1847-1871"), to correlate yield with total annual rainfall. More usually distribution must be taken into account, as was done by Walter (*loc. cit.*) for Mauritius and by Leake (*Proc. Roy. Soc.*, B, 103, 1928). From the economic point of view, however, of almost equal importance is the occurrence and regular incidence of a dry season. With the commencement of the dry season growth is checked and the cane matures, sucrose content attaining a maximum and glucose content a minimum—points which are of vital importance for efficiency in the factory. Unseasonal rain during the crop season leads to renewed growth and a drop in sucrose content of the cane.

As might be expected in a crop vegetatively reproduced and of which, in consequence, large and contiguous areas are occupied by what are merely vegetative offshoots of a single plant, disease has repeatedly assumed epidemic form. Some of these diseases exhibit points of exceptional interest. The Mosaic disease has been responsible for extensive damage in many countries. It was first noted in Java about 1892, later in Hawaii in 1908 and Porto Rico in 1917, and it is now practically world-wide in distribution. Its ravages have been countered by the substitution of resistant varieties; BH 10(12) in Porto Rico, Uba in Natal, and POJ 36 and 213 in the Argentine. These latter owe their resistance to the Indian Chunnee which occurs in their parentage. It can be kept under control also by the removal of all attacked stools as soon as they are identified. Mosaic has now come to be recognized as a Virus Disease, the infection of which is carried by *Aphis maidis* Fitch among other Aphides (Brandes, *J. Agric. Res.*, xix., 3, 1920; Chardon and Veve, *Phytopathology*, xiii., 1, 1923). Mosaic attacks other crop plants, notably *Zea mays*, and for this reason the practice of taking off a maize crop from a field freshly planted to cane requires caution. (See Virus Diseases.)

Root disease is another common cause of extensive loss in the crop. Numerous fungi are associated with the disease, notably *Marasmius sacchari* Wakker. The disease, however, appears to have a physiological basis to which the associated fungi are secondary. It may be produced by a number of causes which render the cane susceptible to attack at the root, and the destruction of the root system leads to a condition of physiological drought which is the most prominent

SUGAR-CANE (*Continued*)—

symptom of the disease. Primarily, it is a case of maintenance of a healthy condition in the plant, which is an agricultural problem, but varieties show a marked range of susceptibility. Replacement by resistant varieties is, therefore, one means of reducing the loss due to this disease. It is, probably, its susceptibility to this disease that led to the replacement of the Bourbon (Otaheite) cane in many countries, though the most prominent symptom was susceptibility to Red Rot (*Colletotrichum falcatum*, Went.) and to Rind Disease (*Melanconium sacchari*, Massee).

Sereh is another disease due, apparently, to a Virus, though little is understood as to its exact nature in spite of a large volume of work. Doubt even attaches to its infectiousness. It was responsible for serious loss in Java in the early eighties, and is reported from a number of countries. It, again, has been countered by the substitution of resistant varieties, notably those containing a Kassoer parentage.

Another disease, which has, however, assumed serious proportions only in Trinidad, is the Froghopper Blight. It is in the ecological aspect of the disease, as disclosed by the work undertaken in connection with it, that the main interest lies. The Froghopper (*Tomaspis varia* Fabr.) occurs in some seasons in swarms, the imago feeding on the sap secured by puncturing the leaf epidermis and the nymph lying protected by its spittle on the cane roots. In one view the prominence of the disease in recent years is an example of the unforeseen disturbance of the balance of nature due to the importation, in this case of the mongoose, of exotic organisms. The rapid spread of the mongoose has led to the diminution of reptiles and ground-nesting birds, which are the natural enemies of the froghopper. This aspect has been minutely investigated by Williams (*Mem., Dept. Agric., Trinidad and Tobago*, i., 1921). More recent serious outbreaks led in 1926 to the establishment of a Froghopper Committee, the work of which indicates that the fundamental cause is physiological. Under certain cultural conditions the plant is unhealthy, and is not able to isolate the cells of the leaf which have received injury from the puncture of the insect. The neighbouring cells are affected, and a dead area results. In heavy attacks these dead areas become confluent, and give to the field the scorched aspect which is typical. The work further shows that these conditions are associated with a deficiency of combined calcium in the soil. The solution, therefore, is to be found less in a direct attack on the insect than in an improvement, through cultural practice, of the health of the cane plant itself.

Other diseases which have attracted attention as causing serious loss are Gum Disease (*Bacterium vascularum* Cobb) and, among insects, numerous stem borers, notably *Rhabdocnemis obscura* Boisd. This latter was brought under control by Muir, who introduced a Tachinid parasite (*Cercomasia sphenophori* Vil.) from Amboina to Hawaii about 1910 (Muir and Swezey, *Ent. Bull.* xiii., *Exp. Sta. Hawaiian Sugar Planters' Assn.*, 1916). This, and the control of the Sugar-Cane Leafhopper (*Perkinsiella saccharicida* Kirk.) by the

SUGAR-CANE (*Continued*)—

introduction of the Chalcids (*Paranagrus optabilis* Perks. and *Ootetrastichus beatus* Perks.) from Queensland and Fiji respectively, by Koebele in 1905, afford two early examples of biological control.

The accompanying table* indicates the world production of sugar from the cane, and the contributions which the various countries of the Empire make towards this total:

	Tons. 1928-29.		*Acreage.* 1927-28.
Australia ..	532,034		291,299
South Africa	264,285		264,352
British India	2,735,000		2,958,000
Kenya	—		9,408
Uganda	—		8,570
Mauritius	247,752		157,731
Straits Settlements	—		32
Ceylon	—		800
Fiji ..	98,683		49,000†
British West Indies			
Barbados ..	246,814	35,000	158,054
Grenada ..		5,000	
Jamaica ..		45,000	
Antigua ..		16,480	
St. Kitts-Nevis		17,000	
Montserrat ..		150	
Virgin Islands ..		100	
St. Lucia ..		4,750	
St. Vincent ..		1,700	
Trinidad and Tobago		32,874	
British Guiana .. .	116,578		53,489
Total Empire	4,241,146		
World Total	17,831,146		

† For 1926-27.

India—India holds, in many respects, a unique position as a sugar-producing country. Though it stands second only to Cuba in the magnitude of its output, it is not self-supporting, and meets the balance of its requirements by the importation of approximately a quarter of what it produces. Although it produces so largely, that production is almost entirely secured by the primitive method of boiling down the juice in open pans after extraction by mills driven by cattle power. There are, it is true, central factories of modern type in certain areas, notably Bihar, but the fraction of the entire crop handled by these is insignificant. The reason is dual; the first and main reason being the preference of the population for crude sugar, or "gur"; the second, the difficulty of organizing supplies in a country of peasant holdings. Finally, although a large proportion of India lies within the tropics, the centre of cultivation lies in the United Provinces outside the tropics. This somewhat peculiar distribution of the crop is the consequence of the extravagant demand, relative to most other crops (exclusive of rice), for water. India, with

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* *Figures kindly supplied by the Sugar Federation of the British Empire.*

SUGAR-CANE (*Continued*)—

its continental climate, has its rainy season over most of the country limited to some three or four months, and the critical factor in cane cultivation is the water supply of the remaining portion of the year. There are three main tracts in the United Provinces: a westerly tract, centred on Meerut, where canal irrigation is available; a north-central tract, centred on Bareilly, where irrigation is of less importance; and an easterly tract, centred on Gorakhpur, where irrigation is reduced to a minimum. This latter tract is continuous with the Bihar tract. This lesser need for irrigation in the two latter tracts is due to the relatively high humidity, and, in the easterly tract, to the peculiar soil conformation which permits an upward flow of water from the water table throughout the dry weather. But, even so, water is a definite limiting factor, and the only canes widely cultivated for the production of "gur" are the hardy Indian varieties—thin, or *ukh*, and medium, or *ganna*, canes. A further limiting factor is temperature, which checks growth and, concurrently with the termination of the rains, causes the cane to ripen about December. A third limiting factor is manure, and an immediate response is given to adequate supplies of organic material. As Clarke has shown at Shahjahanpur (*Bul. Econ. Indo-chine, New Series*, xxiii., No. 144, 1920), yields of up to 40 tons cane may be obtained when adequate supplies of water and manure are available. In addition to the above canes, thick, or *paunda* (Noble), canes are cultivated in the neighbourhood of towns. The conditioning factors for their growth are the available supplies of manure from the cities and a market for the produce, which is sold for chewing.

In the Punjab the more rigorous, and longer, cold weather offers too severe a limitation to the cultivation of all but the hardiest varieties, and this led Barber to study the Punjab types as the most primitive and nearest to *S. spontaneum*. On this supposition the Indian canes originated somewhere near the head of the Bay of Bengal, and the earlier types were successively thrust out to the limits of cultivation as better, but less hardy, canes were developed.

In Central and Southern India temperature ceases to control cane cultivation to the same extent, and water becomes the dominating factor. Where adequate supplies of water are available *paunda* cane is grown.

The improvement of the cane crop in India is intimately bound up with the raising of the general standard of agriculture of the country. (See Indian Agriculture.) Ratooning is rarely practised, and the crop fits into the rotation adopted by the peasant cultivator. Given an adequate water supply, there still remains the question of manure, and a sufficient dressing of manure will have a residual, but marked, effect on the subsequent crops. The provision of these two requirements will not only largely increase the cane crop, but will automatically raise the standard of agriculture of the cane districts. The cane crop thus occupies a key position in the agriculture of the country, and especially of the United Provinces. It has been found, however, that the local canes, like wheat, are incapable of a full response to the improved conditions, and it has been necessary to

SUGAR-CANE (*Continued*)—

search for new varieties. In Northern India, though many of the varieties arrow freely, no viable seed has been found. It remained for Barber, working at the Coimbatore station, for the establishment of which he was responsible, to lay the foundations for an organized supply of seedling canes for cultivation in Northern India. How far this work has been successful is shown by the extensive and extending area now under Coimbatore seedlings.

The whole problem of sugar production in India is minutely reviewed in the Report of the India Sugar Committee (1920).

The British West Indies—Next to India, the British West Indies, including in that area British Guiana, is the largest cane area in the British Empire. With the major exception of Barbados, production is carried on in central factories of modern type, and the area thus falls into line with the major producing countries of the world.

British Guiana—The main sugar area is on the marsh lands near the sea and below sea level. The land is protected by dykes and intersected by drainage channels, from which the water is drained by pumps or by natural flow at low tide. Dovetailing into this drainage system is a canal system used to transport the crop in barges, and sometimes for irrigation. Irrigation is, however, rarely practised, for it tends to bring to the surface the salts of the subsoil water. As in other West Indian areas, cultivation is mainly conducted by hand labour formerly recruited from India under a system of indenture. The tract is peculiar in that there are two crop seasons in September to December and in May and June, a fact due to the seasonal distribution of the rainfall. Seedling canes were early raised by Harrison, and several of the D series, notably D625, have been extensively cultivated.

Trinidad—Cane is grown on the lower lands of the west of the island. Ratooning is freely practised, some five or six cuttings being secured before the land is replanted to cane. Frequently 80 per cent. and over of the cultivated area is under cane at the same time. As in British Guiana, irrigation is rarely practised. The single crop season lasts from February to May, coincident with the dry season. Trash as a manure is supplemented by pen manure made on the Mauritian system. A considerable portion of the crop is raised on the "farming" system, land being leased to small cultivators, or cane being issued to those owning their own land under a contract to supply to the factory. The whole problem of cultivation has been raised by the losses suffered from the froghopper blight, and is being minutely investigated (see above).

Barbados—The introduction of cane into the island dates from 1641, and Barbados was the first British colony to take up the production of sugar from the cane. The industry here presents certain peculiarities. The island is mainly composed of coral rock, absorbing and holding the rain, so that cane is here grown without irrigation on a lower rainfall than elsewhere. It is also peculiar in that the unit of production, as well as of manufacture, remains small. Originally

SUGAR-CANE (*Continued*)—

"muscovado" sugar was the main product, and prepared in open pans, but much of the crop is now consumed in the preparation of fancy syrup. Cultivation is by hand labour, and attains a very high standard. The work of Harrison and Bovell in initiating the raising of seedling canes has already been noted, and some, notably BH10(12), have been widely cultivated both in Barbados and elsewhere.

Other Islands—The other islands, of which Jamaica is the largest producer, offer no especial peculiarities.

Australia—Australia is a country with a continental climate, and cane is restricted to a narrow belt along the coast of Queensland and the extreme north of New South Wales. Economic, and not cultural, questions dominate the situation in this tract, for it is the only tropical tract where cane is grown entirely by white labour. Production centres on central factories, and the cane most commonly cultivated is the Badila, derived from New Guinea, though local seedling canes have been raised and enter into cultivation. Particulars of cultivation have been given by Easterby (*B. of Sugar Exp. Sta. Bull.*, 3, 1924).

Natal—The cane area of South Africa is confined to Natal and Zululand. Most of the cane is grown by independent farmers with paid native labour. The area is, generally speaking, subtropical, and a crop is obtained every second year only. The variety universally grown is the Uba, of doubtful origin, but definitely an Indian type. Its introduction was the result of the loss caused by mosaic. One consequent difficulty is the short crop season, and there is definite need for other varieties with a late and early maturing habit.

Mauritius—In the economic aspect Mauritius offers striking similarities with Barbados. Sugar dominates, almost to the exclusion of other products, and practically all the cultivation is conducted with manual labour of East Indian origin. Here the similarity ends. The soil is of basaltic origin and rich, and the crop is handled in central factories. The industry is of old standing, dating from early in the eighteenth century. Rainfall is adequate, and irrigation adopted only to a slight extent. The crop suffers from the hurricanes which devastate the island, and it was with a view to establishing a system of insurance for loss due to hurricanes that Walter evolved his scheme for evacuating the crop from the rainfall. Mauritius is responsible for the system of preparing pen manure which bears its name, a system which has been widely adopted in the West Indies, while green manuring is extensively practised. Mauritius, too, has been industrious in the matter of importing new canes, while it has been the source from which many countries have derived their supply of cane in the first instance. White Tanna is still most generally cultivated, but is being supplanted by D74, BH10(12), and local seedlings. It is noteworthy that, as early as 1891, Perromat raised seedling canes which have become known as the MP series. The Mauritian industry has been described in great detail by Walter ("The Sugar Industry of Mauritius").

SUGAR-CANE (*Continued*)—

Fiji—Cane is an important crop in this distant island. Cultivation is good, and a double green crop is usually ploughed in. Disease causes much damage, Mosaic and "Fiji disease" (Reinking, *Phytopathology*, xi., 8, 1921) being the more important, and ratooning is, in consequence, limited to a single crop. Badila appears to be the most resistant, and is the cane most commonly cultivated.

The literature of cane is so large that only selected references have been possible. Current literature is reviewed in great detail in the *International Sugar Journal*.

H. M. L.

SULPHATE OF AMMONIA—See Fertilizers.

SULPHUR AND ITS COMPOUNDS (Sulphur, symbol, S; atomic weight, 32·064; atomic number, 16) is an element found to a considerable extent native, and in great quantities in combination. The commercial supply of the element itself is largely obtained by purification of the native supplies, but also, in Germany, to some extent, by boiling calcium sulphide and magnesium chloride in solution in water and burning the sulphuretted hydrogen evolved with a limited air supply, by which means the sulphur is deposited. It exists in a large number of allotropic forms, most of which appear to be polymeres. It is marketed in three forms: "roll-sulphur," which is moulded direct from the melted element after purification; precipitated sulphur, including "lac-sulphur" and "milk of sulphur," and in this class also falls the sulphur deposit on plants from lime-sulphur spraying; and, finally, "flowers of sulphur," formed by direct condensation from the vapour to the solid state.

The element is of interest to the agriculturist chiefly in its use as fertilizer, fungicide, insecticide, and fumigant. As regards the first three of these, reference may be made to the articles on Fertilizers, and Insecticides and Fungicides. As a fumigant it is dealt with below.

Plant roots take up sulphur as sulphates, but in both plant and animal tissues it is present almost entirely as organic sulphur, chiefly in the form of cystine radicles (see below). Cystine also is almost the only sulphur compound resulting from breakdown of protein matter. Some plants, *alliums*, and some of the Cruciferæ, produce allyl sulphides and thiocyanates, and the taurocholic acid of the bile of animals contains sulphur. Sulphur is present in hæmoglobin and in exceptionally large quantity in the keratins of horns, hoofs, claws, etc., and in the neurokeratins appearing in the neuroglia of the central nervous system.

Excretion of sulphur by animals is mainly by the kidneys. In the urine it is present in three forms—namely, inorganic sulphates, in which form the greater part is carried away; ethereal sulphates so-called, chiefly indoxyl and skatoxyl sulphate, formed from the small quantities of indol and skatol absorbed from the gut, and finally "neutral sulphur," comprising cystine, thiocyanates, and in some animals variously combined mercaptans.

Phanerogams take up sulphur only as sulphate, but some fungi can

SULPHUR AND ITS COMPOUNDS (*Continued*)—

make use of sulphites and thiosulphates. This preference for sulphate is remarkable, as the sulphate is always reduced in the plant, but the chemical side of sulphur assimilation is unknown.

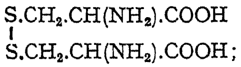
As in the case of nitrogen, so in that of sulphur, there is a cyclic process of which we have seen one-half. The other side—namely, the oxidation of sulphur in the soil—was first shown by Winogradski to be the work of certain oxidizing bacteria named Beggiatoa. (For a full description of this organism and its work see S. Kostytchew, " Pflanzen Physiologie," Berlin, p. 193 *et seq.*, 1926.)

Sulphur Dioxide (SO_2) is made usually by burning sulphur in air, and is used as a fumigant for disinfecting purposes, but is very injurious to plant life. Sulphur is now made in the form of candles, with special wicks for burning, and this is a very convenient form to use in generating the oxide. *Sulphur trioxide* (SO_3) is the anhydride of sulphuric acid.

Sulphuretted Hydrogen (H_2S) is a common constituent of many natural waters, especially those rising at a temperature above the normal, and in volcanic districts. It is a gas with an unpleasant smell commonly compared to that of bad eggs, but the resemblance is less close than is generally supposed, the latter odour being a mixture of sulphuretted hydrogen with other evil-smelling components. Normally toxic to plants, there are yet some which flourish in water containing it, and these are found to be furnished with nodules of Beggiatoa similar to those of the *Bacillus radicicola* or leguminous species.

Carbon Disulphide (CS_2) has been separately treated of, and reference may also be made to the article on Insecticides and Fungicides.

Cystine—The form in which sulphur chiefly occurs in the bodies of plants and animals is di-β-thio-α-amino-propionic acid:



$$\begin{array}{l} S.CH_2.CH(NH_2).COOH \\ | \\ S.CH_2.CH(NH_2).COOH; \end{array}$$

the sulphur is not normally separated from the cystine molecule in digestion, but it may be built up into the tissues also to some extent from the other sulphur groupings taken into the digestive tract, such as sulphides and thiocyanates in plants. (See Proteins.)

SUNFLOWER CAKE AND CAKE MEAL—For composition and feeding value see Feeding Stuffs; also Poultry, Nutrition.

SUPERPHOSPHATE—See Fertilizers.

SUSSEX GROUND OATS—For composition and value when fed to poultry see Poultry, Nutrition; also Oats.

SWINE, Food Requirements of—See Foods and Feeding.

TALLOW—The rendered body fat of ruminants, usually of the ox or sheep. Its composition and firmness depend to some extent on the feeding of the animal. Its mean composition is 16 per cent. stearin, 6 per cent. palmitin, and 33 per cent. olein. That from Russia is

TALLOW (*Continued*)—
valued for its hardness, the oxen being fed largely on hay. There are also a large number of vegetable tallows obtained from the fruits and seeds of a number of tropical plants, of which the chief are *Sapium sebiferum* (Euphorbiaceæ), cultivated in America; the Malayan *Nephelium lappaceum* (Sapindaceæ), of the same genus as, and with edible fruit like, the litchi of India; *Pentadesma butyracea* (Guttiferæ), now becoming known also as a stove horticultural subject for the beauty of its flowers and fruit; and *Butyrospermum Parkii* (Sapotaceæ). These vegetable tallows are used in dressing cloth, making candles, soap, cheap chocolates, etc. Only the animal product should be used for electric motor commutators.

TAPIOCA FLOUR—For composition and feeding value see Feeding Stuffs.

TARES—See Vetches and Tares.

TEASEL (*Dipsacus fullonum*), by some authorities considered to be a cultivated form of *D. sylvestris*, a common weed in hedges and copses, is a tall, prickly, biennial plant with long, sessile, lanceolate, coarsely toothed leaves, mostly cup-like at the base. The inflorescence, which is lilac coloured, occurs in terminal heads, at first ovoid, but later becoming cylindrical, and varying up to 3 ins. in length and about an inch in width. The heads are furnished with an involucre of eight to ten long, stiff, upwardly curved prickly bracts.

To each flower there is a broad scale terminating in a fine curved point, whilst at each side of the curved point or hook there are numbers of still finer hooks. When fully ripe these scales, which are attached firmly to the receptacle, become tough and woody, and the hooks are able to attach themselves with considerable tenacity to such material as cloth. The heads or "teasels" were, and are still used extensively for raising the "nap" on woollen cloth of finer qualities. As the "nap" is raised while the cloth is wet, the fineness of the teasel hooks, added to the fact that they do not rust, renders them superior to wire brushes for this particular operation.

The cultivation of teasels is still carried out on a relatively extensive scale in Somerset. A good loam to a heavy soil appears to be the best suited to the crop, which requires a plentiful supply of moisture up to the time of flowering. Afterwards, bright dry weather from July until harvesting is essential, as it toughens the hooks of the teasel and the adherence of the scale as a whole to the receptacle. On the other hand, in persistently wet weather rain is liable to become lodged in the teasel head, where it rots the base of the scale, and so renders the head useless.

The seed is sown in a fine seed-bed at the rate of 2 pecks (=12 to 13 lbs.) per acre, in March or early April, either broadcast or with a drill. In November and December the plants are transplanted at the rate of about 16,000 per acre, and in such a manner as to permit of thorough cleaning and cultivating during the following spring. It is essential also to leave sufficient space between the plants to allow free movement of the cutters during harvest.

The crop is ready to harvest in August, when the teasels are cut

TEASEL (*Continued*)—

separately by hand, graded and counted. The teasels are sold by the "pack" of 20,000. There are usually three grades: the "Kings," which are the first ready for cutting, then the "Mediums," and finally the "Buttons."

The average yield is about 8 packs = 160,000 teasels per acre.

REFERENCES.—H. W. Ashby, "Some Minor Farm Crops *v.* Teazles," *J.R.A.S.E.*, vol. lxxiv., 1913; Wilson, "Our Farm Crops," Blackie and Son.

TEMPERATURE—A property of bodies in virtue of which they are able to part with heat to other bodies, which are then said to be at a lower temperature than these. It may be described as "heat potential." Care should always be taken to distinguish between temperature and heat; a small body like a grain of sand, even at a red heat, might, indeed would, contain far less heat than a pound of ice, but its temperature would of course be much higher. The lowest temperature conceivable is $-273°$ C., called the *absolute zero*, since at that temperature all molecular motion would apparently be abolished, and it is this motion of the molecules which makes itself apparent to our senses as heat. (See Heat, Thermometers.)

THERM—Heat unit = 1,000 kg.-calories. Nett energy values of feeding stuffs are very commonly expressed in therms/100 lbs.

THERMO-ELECTRIC COUPLES (Thermo-junctions)—When two wires of two dissimilar metals are joined at both ends so as to form a closed loop, an electric current will flow round the loop continuously without any battery or other obvious source of power, *except* when the two junctions of the wires are at exactly the same temperature. The strength of the current, which is always very small, requiring a highly sensitive galvanometer for its detection, varies, over considerable temperature ranges, sensibly as the difference in temperature between the junctions, and so may be used to measure this. Pairs of metals in common use for this purpose are platinum=rhodio-platinum, platinum=iridio-platinum, copper=constantan, and copper=iron.

THERMOMETERS—A thermometer is an instrument for measuring warmth—that is to say, temperature (*q.v.* also Heat and Calorimeter). The thermometers in most common use consist of some liquid such as mercury or coloured alcohol enclosed in glass, the expansion of the liquid, which is always greater than that of the glass container, causing the liquid to rise in a narrow capillary stem. Fahrenheit found that mercury expanded 180 ten-thousandth parts of its volume between the freezing and boiling points of water, and he therefore divided this temperature interval into 180 parts. Proceeding further, he found that the coldest temperature he could obtain with ice and salt was 32 of these degrees below the freezing point of water, and he called this point zero, and the freezing point of water 32°; the boiling point thus became 212°. His thermometer, though it has nothing to recommend it, is generally used throughout the British Empire except for scientific purposes; indeed the meteorologists still

THERMOMETERS (*Continued*)—

employ it. Another type, produced by Réamur, is largely used in Germany; on this scale the freezing point of water is 0°, and the boiling point 80°. For scientific purposes throughout the world a thermometer is employed in which the temperature interval between the melting point of ice and the temperature of the steam above water boiling under normal pressure (760 mm.) is divided into 100 degrees. Where the greatest accuracy is in question the melting ice must also be under normal pressure. Such a thermometer is said to be graduated on the centigrade scale, and is referred to in England as a centigrade thermometer, on the Continent more usually by the name of the inventor, Celsius.

To convert temperatures on one of these scales into either of the others Fig. 30 may be used.

Where a more precise equivalent than can be obtained from the Figure is required, one may compute thus:

$$C=\tfrac{5}{9}(F-32)=\tfrac{5}{4}R.$$
$$R=\tfrac{4}{9}(F-32)=\tfrac{4}{5}C.$$
$$F=\tfrac{9}{5}C+32=\tfrac{9}{4}R+32.$$

The principal liquids used for filling thermometers are mercury, coloured alcohol, and pentane (C_5H_{12}). Standard thermometers are always filled with mercury because neither of the other two liquids can be used where the thermometer is to read as high as the upper fixed point (100° C). Mercury has also the advantage, generally, that it does not distil into the cooler part of the stem as does alcohol when this is not immersed. Furthermore, a narrower capillary can be used with mercury, thus reducing the correction required in accurate work for the exposed part of the stem.

On the other hand, owing to the greater expansibility of alcohol relative to glass, the bulb of an alcohol thermometer may be made very much smaller than that of a mercury thermometer of the same bore, and variations in the volume of the bulb are of less importance. Partly as a consequence of this, taking into account also the differences of specific gravity and specific heat, it may be shown that the heat capacity of an alcohol thermometer is *ceteris paribus* very much less than that of a mercury one. Another important advantage of alcohol thermometers for use where rate of change of temperature is in question is that since alcohol wets the sides of the capillary the motion of the column is steady whether rising or falling. In a mercury thermometer the movements of the mercury column are always more or less jerky; this is very much less in evidence in a rising column, consequently in using a mercury thermometer it should always, in accurate work, be cooled below and allowed to *rise* to the temperature required. Finally, mercury freezes at just below −39° C., and consequently readings below this (mercury contracts on freezing) indicate nothing whatever as regards the temperature except that it is below this point. Alcohol does not freeze till −114° C., and pentane not till −131° C. Pentane has, moreover, a greater cubical expansion than alcohol.

Of the corrections to which thermometer readings are subject some

THERMOMETERS (*Continued*)—

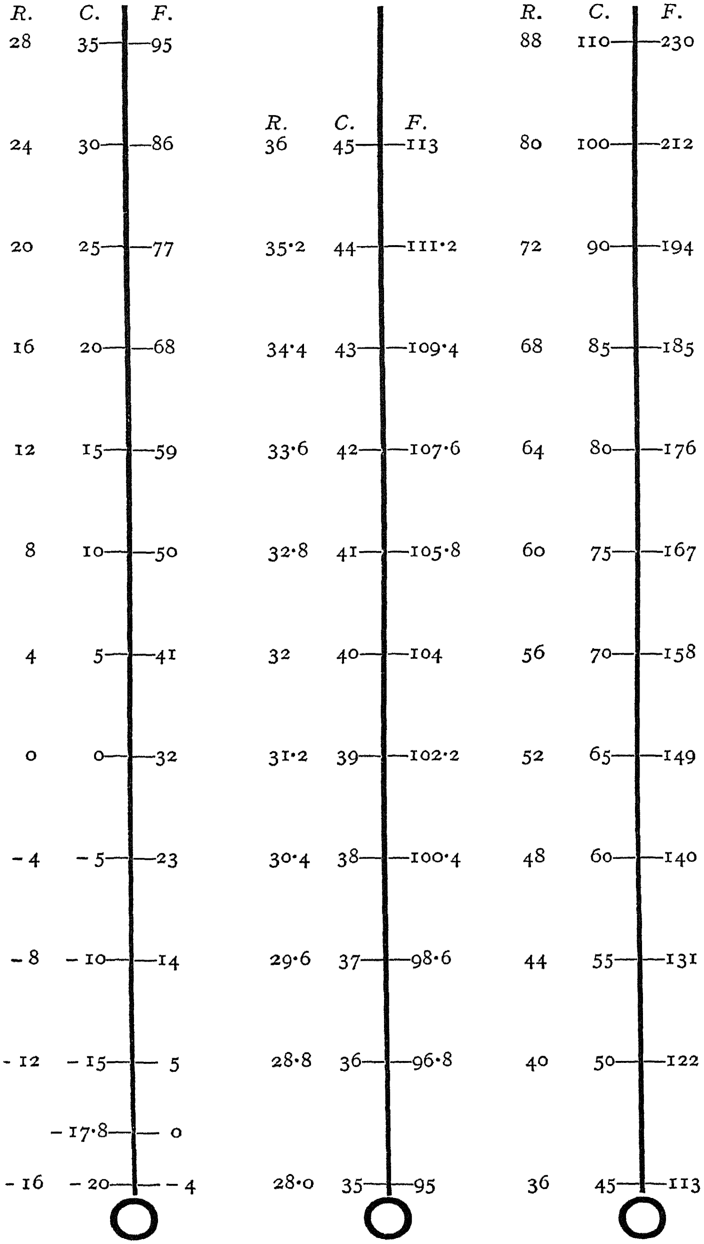


FIG. 30.—COMPARISON OF THERMOMETER SCALES.

THERMOMETERS (*Continued*)—

demand a short mention, while others, such as pressure, scale, and Poggendorf corrections, do not affect the farmer or agricultural scientists and will not be further animadverted upon. All thermometers are subject to change of zero. There is, first of all, the *secular rise* caused by remainder effects of strains in the material of the container, usually glass, caused in the processes of manufacture and imperfectly removed by subsequent annealing; and, secondly, there is the *temporary depression* after the thermometer has been exposed to a high temperature around the top of its range, due to the fact that the glass does not immediately recover from the expansion to which it has been subjected. This depression may amount to as much as $\frac{1}{10}$ degree in the best thermometers, and may persist for as much as two or three weeks. Where a length of the liquid column is exposed to a lower temperature than the bulb the reading must be increased in the case of a mercury thermometer by $0{\cdot}00016\,nt$ where n is the number of degree divisions corresponding to the length of the exposed mercury column, and t the mean approximate temperature difference between the bulb and the exposed portion. For alcohol the theoretical formula is $0{\cdot}00099nt$, but is inaccurate owing to distillation. The stem should, moreover, be calibrated for inequalities of bore by detaching a length of the liquid and noting the number of degree divisions occupied at different parts of the scale. Unless these precautions are taken, and the zero frequently determined, temperatures cannot be determined generally with an accuracy of more than about half a degree. Where much greater accuracy is necessary a considerable saving of trouble is effected by purchasing a thermometer with a certificate from the National Physical Laboratory which gives the corrections to the standard at each two, five, or ten degrees as the case may be, but of course the correction for zero changes and exposed stem have still to be applied.

For some purposes it is desirable to know the maximum and minimum temperatures recorded over a certain time interval. Thermometers for this work are of many patterns, but in all cases there is an index of some sort which is so light as to be entrained by the liquid meniscus in rising or falling when the thermometer is placed horizontally. In this way an index pushed before a mercury column will indicate by the position of the end nearest the mercury the maximum to which the thermometer has risen, and, similarly, a light index immersed in an alcohol column will be entrained by the meniscus and left at the lowest point to which this sinks. In the clinical thermometer, which indicates maximum only, a fine constriction in the capillary below the scale breaks the mercury thread as soon as the mercury in the bulb begins to contract, thus leaving the detached portion registering the maximum temperature to which the bulb has been exposed.

For gas thermometers, resistance thermometers, pyrometers, etc., which do not concern the agriculturist unless in exceptional cases, reference must be made to some good physical textbook.

T. D.

THRASHING—The ideal in thrashing is to obtain the greatest possible quantity of clean, uninjured, germinative corn, and complete separation of the straw, cavings, weed seeds, and chaff. The attainment of this ideal depends not only upon the type, condition, and management of the thrashing machine, but also on the variety of corn, the condition and ripeness of the crop, the plumpness of the grain, and other crop factors. Well-ripened and well-harvested crops generally thrash most readily, and straw free from weeds and other bottom growth gives least trouble.

In the most familiar type of British thrasher—including all the large itinerant mills—the grain is extracted from the ears by beater bars on a drum rotating at high speed within a barred concave which partially encircles the drum. The beaters, which usually number eight, are situated transversely on the circumference of the drum and have ribbed faces; and the concave consists of a wire grating with plain rectangular transverse bars. The beaters knock out the grain partly by impact and partly by rubbing the ears against the edges of the concave bars. The corn and chaff drop through the grating, and the straw passes forward to the shakers.

The position of the concave in relation to the drum is variable within certain limits, and its correct setting is most important. The normal spacings for cereals are 1 in. between beater and bar at the top or mouth end, $\frac{1}{2}$ in. at the middle, and $\frac{3}{16}$ in. at the bottom or exit end. The actual setting, however, must be varied according to the needs of each case, soft grain requiring the close setting, and harder grain, including malting barley, a wider spacing. Too close adjustment must be carefully avoided where it is essential to preserve the grain from injury, as in the case of seed corn and barley for malting. Some feeders—who invariably feed the grain at one side of the drum and the straw at the other—prefer a wider setting of the concave at the side receiving the butt end, and this is undoubtedly desirable when dealing with sheaves containing much bottom herbage. The above adjustments are easily made by means of screws, three on each side of the machine, with pointers indicating the spacings at each position.

In machines that have been in work for some years without attention to the condition of the drum and concave, there is often difficulty in securing a satisfactory extraction of the corn without breaking a percentage of the kernels. This is due to the drum and beater bars having worn more in the middle than at the ends, and the trouble may be aggravated by the bars of the concave having become bent outwards. The remedy—unless the parts require replacement—is to reverse the concave, straightening the bars if necessary, and to bring up the beater bars in the middle by packing them in the centre. Care, however, must be exercised to preserve the equilibrium of the drum. The drum bearings should also be kept in good condition.

Emphasis must be laid on the machine being driven uniformly at the correct speed as specified by the makers, commonly about 1,000 revolutions per minute in a drum of 22 ins. diameter. Drums of larger

THRASHING (*Continued*)—

section require slower drive, and peg mills are adapted to run at about 600 revolutions per minute. Drum speed affects the work of the straw shakers and sieves as well as the drum itself. Over-driving breaks grain and disturbs the balance of arrangements for separating and grading; too slow speed entails loss of grain in the straw and poor separation. Over-feeding, lack of power, and defects in the driving mechanism may be responsible for lack of drum speed. The engine used to drive a thrasher must have ample reserve power and good governors to maintain steady running throughout.

The feeding of the drum is an important duty, the ideal being to supply the drum with a steady stream. Irregular feeding causes loss of corn, broken grain, bad work by the sieves, and stoppages due to the wrapping of straw and rubbish round the drum. When feeding sheaves of moderate length, the crop enters the mouth of the machine parallel with the bars. More even wear of the bars is ensured if the heads are fed alternately to left and right. There may, however, be reason to feed all sheaves in the same way, as, for instance, when straw is required for thatching or when the drum has been set to deal with sheaves containing much bottom growth. Long straw must be fed in obliquely; but endways feeding is not good practice when using a high-speed drum, as it causes loss of grain as well as untidy straw. The modern tendency is to adopt mechanical or " self " feeders, which not only save labour but also deliver the corn to the machine at a more uniform rate than hand feeding. The fitting of a governor prevents the conveyor from starting until the machine has attained the requisite speed; and if the machine slows down the conveyor stops automatically until the drum has cleared itself and regained the proper hum.

All thrashers are dependent on level setting for the proper action of their sorting mechanism; bad setting also unbalances the drum and causes undue wear of the bearings.

Among other adjustments necessary for proper working may be mentioned the regulation of the blowers, the setting of the screen, and the adjustment of the awner and polisher. Special mention must be made of the care required in awning barley intended for malting purposes; maltsters prefer a little beard left on the end of the grain rather than that the germ should be injured or the grain " skinned " and thus rendered liable to mould during malting.

The finishing thrasher above dealt with not only thrashes out the grain, but also winnows it thoroughly ready for seed or market. Machines of simpler type, costing less and requiring less power and attention, are made to suit different needs. In many of the small mills the peg type of drum is fitted instead of the beater bar type. The peg type of drum is characteristic of American as well as Scottish thrashers; it has one special disadvantage, which does not count much where straw has little value, viz., it breaks the straw into pieces.

Following American developments the steel thrasher has made its appearance in this country. It is specially adapted for tractor work and haulage, and its light weight allows of its being used for thrashing in the field where a standard travelling mill could not be adopted.

THRASHING (*Continued*)—

The drum is of the peg type, and straw, chaff, and cavings are blown clear of the machine by means of a swivelling wind stacker.

Finally, mention may be made of the harvester thrasher, which thrashes the crop as it is cut. In countries where large acreages of grain are cultivated and where harvest is carried out under dry conditions, the combined thrasher harvester has already been widely adopted. Under British conditions, however, its use is limited to certain districts and to farms large enough to justify the purchase of grain-drying equipment as well as the combine. J. R. B.

THYME—See Herbs, under Market Gardening.

TILLAGE—Crop plants such as wheat and potatoes do not produce harvestable yields except where grown under man's care and protection, and even the desirable species of grass-land herbage attain dominance over the objectionable species only where they receive artificial aid in the struggle for existence. The various operations—manuring, draining, weeding, tilling, etc.—whereby crop plants are enabled to possess the ground and thrive, are all comprised by the term "cultivation." Tillage is one branch of cultivation, viz., the treatment of the soil with implements for the purpose of bringing about and maintaining conditions which favour the growth of crop plants.

Jethro Tull's conception of the effect of tillage as a factor in crop production was that working the soil increased the supply of fine particles, which he imagined were ingested as food material by the root fibres. A very similar philosophy has prevailed to this day, the difference being that it is now generally known that plant roots take up nutrients in the dissolved instead of the solid form. In the belief that available plant food can be liberated from the inert mass of soil material by tillage operations, the farmer has been urged to increase the number of his soil workings, to cultivate to a greater depth, and to utilize machines which, apparently, subjected the soil to more drastic treatment than the ordinary implements. Whatever may be the connexion between a well-prepared tilth and satisfactory crop growth, however, it is certain that the operations of tillage have no appreciable immediate effect on the size and solubility of the ultimate particles of which soils are composed. A rational philosophy of tillage can be built up only on the basis of the recognizable effects and objects of the various processes.

The first and most obvious reason for breaking up and stirring the soil after harvesting one crop and before sowing the next, is to clear the ground of existing vegetation whose growth would compete with that of the plants intended to be grown. Crops such as wheat, which afford only limited opportunities for weed destruction during their growing period, are customarily followed by roots, which permit of preparatory cleaning operations and also of inter-tillage after planting. Undoubtedly, the series of tillage operations in the cultivation of a root crop is determined largely by the nature and extent of the weed infestation left by the previous crop. Under certain conditions—excess of perennial weeds, very heavy soil, inability to clean in autumn

TILLAGE (*Continued*)—

—the cropping for the cleaning season may be wholly or partially subordinated to the object of eradicating weeds. Thus, the field may be summer-fallowed, half-fallowed and drilled with a late-sown crop such as common turnips or rape, or the crop may be kale or potatoes if the delay, etc., caused by cleaning operations has made the sowing of mangolds or beet too risky.

If the soil is not occupied by weeds but by crop plants such as grass and clover, this vegetation must be treated in the same way as weeds, in the sense that it must be removed from the sphere of competition with the next crop. Cultivating when the soil is dry is one method; skim ploughing followed by working with tine implements is another; ploughing the herbage under, so as to cover it completely, is a third. All three methods have the same principal object—to kill the existing vegetation. If this work is done some weeks in advance of the sowing of the next crop, the seedling growth of the latter is favoured because of the better decay of the residues of the previous vegetation; fibrous matter becomes humus, improving the physical condition of the soil; and by the nutrification of these vegetable residues, plant food is made available which would be still locked in the fresh tissues of a turf that had only just been ploughed.

The second also obvious reason for tillage operations is to loosen and refine the soil to allow of seed being deposited at the appropriate depth and being covered with soil that is fine enough to protect the seed from drought and to hide it from birds. Tillages are often directed specially to this object, as for instance the superficial workings preparatory to sowing beet or mangolds on land that has been deeply ploughed during the previous autumn or winter. Another instance is the shallow tillages associated with the sowing of grass and clover seeds.

The depth of covering appropriate to the various seeds—and therefore the depth of tillage necessary at this stage—is not related to the depth of rooting of the respective species. Clover and lucerne, for instance, are notoriously deep rooters, but require shallow sowing. Depth of cover is determined by a number of factors. Small seeds do not *commence* to germinate when lying below more than about an inch of soil; large seeds will penetrate 4 or more inches. The actual explanation of this difference is not clear, but it is well known that the seeds of weeds such as charlock and spurrey do not grow until brought up into the top layers, though beans will push through a furrow of normal depth; presumably small seeds require more oxygen than larger seeds. Depth of sowing also depends on moisture conditions. When moisture is abundant, as is commonly the case in autumn sowing, seeds left near the surface (if not taken by birds) come up before those buried deeper. In spring, however, heavier covering may be needed to ensure adequate moisture supplies. Hence, spring cereals require deeper drilling than is advisable for late-sown winter wheat.

In preparing the seed-bed for any crop, due regard must be paid to the intended depth of covering, and to moisture conditions. The

TILLAGE (*Continued*)—

smaller the seed, the finer the seed-bed needed; for if such seeds are drilled in a coarse tilth, many will percolate to depths below that at which germination will take place; the soil will generally be too dry for germination at the depth ideal for this type of seed; and with coarse material at the surface, adequate covering at a shallow depth is not possible. The best results are obtained when attention can be devoted entirely to the object of preparing the tilth to the depth at which the seed is to be deposited, leaving the under soil undisturbed and comparatively moist. On soils rich in the clay and silt fractions, however, working the surface too fine will introduce the risk of the surface becoming capped and encrusted after rain.

If weed suppression and the preparation of a suitable drilling medium were the only objects of tillage, then it might be suggested that a clean stubble could be prepared for oats by merely superficial working in spring to produce a shallow tilth in which to drill. If roots were to be the spring-sown crop, ploughing and perhaps other workings would be needed to cover and incorporate the dressing of yard manure generally applied to the root crop. The omission of ploughing for oats, however, would not be good husbandry, and the function of this operation in preparing for roots is not merely that of covering manure. The periodical inversion of the soil is, in humid districts at any rate, essential to satisfactory crop growth, not only for the purpose of weed suppression, but also to maintain a good texture of soil. In land not protected by a dense sward of grass, percolating moisture washes the fine-grained and colloidal material downwards, and in the course of a season this results in such a rearrangement of the soil constituents as makes a heavy soil too heavy and impervious in its lower layers, while in a light soil the top layer becomes too coarse and open. By inverting the soil, the fine material is returned to the surface, where under the influence of the weathering agents it is caused to become more friable, and the accumulation of a pan of impenetrable material in the under soil is checked. Periodical inversion of the soil also brings a fresh layer into the region of greatest bacterial activity, which is concerned chiefly with the decomposition of organic matter; without this periodical inversion the top layer would become depleted in humus.

In the cultivation of heavy soils, care has to be exercised in the matter of the time and depth of ploughing so as to attain the desired object of a restoration of the proper distribution of soil particles without interfering with that of obtaining a tilth suitable for the drilling of the seed. Ploughing and weed eradicating, therefore, should be completed some considerable time before the work of preparing the seed-bed begins, so that the colloidal matter brought up may have become weathered and coagulated and, therefore, amenable to refinement for seed-sowing purposes.

Having examined the main principles of tillage, some of the more contentious matters may now be discussed in the light of these principles. Depth of working is a matter on which there is difference of opinion. The advocates of deep ploughing sometimes quote the practice of overseas farmers, who, in certain cases, cut a furrow several

TILLAGE (*Continued*)—

times the depth of the typical British ploughing. Trenching, however, is practicable only where there is little or no distinction between soil and subsoil, as is the case in arid climates. In Britain, very deep work is safe only in exceptional circumstances, as on alluvial soils. On heavy soils the subsoil may be of a very tenacious and intractable nature, and if brought to the surface in large quantities may add very greatly to the difficulty of producing a tilth suitable for germination. If, on the other hand, the depth of ploughing is regularly less than about 5 or 6 ins., and below this the impervious colloidal matter is allowed to accumulate, the soil becomes too wet in winter and too dry in summer; this is because percolation is impeded and the subsoil cannot act as a reservoir of moisture for use in the dry weather. On lighter soils, the deeper the ploughing the better, within reasonable limits. Deep work in this case improves the texture of the soil by increasing the proportion of retentive constituents, which, as already explained, tend to be washed down into the lower layers. If deep work is accompanied by liberal additions of organic matter, so that the soil is enriched in humus to a greater depth, its moisture-holding capacity is improved to the advantage of its cropping power.

Subsoiling is beneficial in certain cases only, viz., where the soil is underlain by an impervious layer that is capable of being broken by the subsoiling operation. In certain soils, although they rest on an impervious layer, this layer cannot be made pervious to water because it is plastic clay; here subsoiling causes no improvement. Where, however, the obstruction is of a gravelly or otherwise brittle nature, its rupture allows the winter rains to penetrate and become distributed through the subsoil, and to enter the drains if in excess. Plant roots are also enabled to go down deeper into the subsoil in search of moisture when the dry season arrives. Thus, subsoiled land in these circumstances lies drier in winter and also withstands drought in summer better than land in which the hard pan persists. Where there is no pan layer below the soil merely stirring the subsoil with a tine confers no benefit, as the act of stirring the subsoil does not accelerate the liberation of such reserves of mineral nutrients as it contains.

Repeated ploughing is thought by some to have a beneficial effect. Admittedly, in certain cases, an additional ploughing in winter may improve the tilth of a clay soil by increasing the amount of soil that has been exposed to the influences which change clay from the plastic to the friable state—frost and alternate wetting and drying. Repeated ploughing may also be an aid to drying the soil for the purpose of killing weeds, as in bare fallowing. Drying the soil also has a partial sterilizing effect, resulting in the active production of nitrates on the return of humidity. For this reason wheat after bare fallow is well supplied with soil nitrates. In the ordinary course of tillage, however, drying the soil is too risky a procedure to be generally adopted.

As regards the degree of looseness or firmness requisite for successful crop production, it is impossible to generalize. Some crops, such as potatoes and barley, require a lighter tilth than others, such as mangolds and clover; but on light soils even barley derives benefit from con-

TILLAGE (*Continued*)—

solidation before sowing, and on heavy soils mangolds may suffer from deficient aeration if the soil is too firm round the roots of the seedlings.

At one time much stress was laid on the importance of hoeing to maintain a loose tilth on the surface for the purpose of retaining moisture. From the benefits which clearly follow hoeing to break a capped or crusted surface, not to mention the essential work of destroying weeds, the importance of judicious hoeing must receive due recognition. It is erroneous, however, to pursue hoeing for the purpose of conserving moisture when the soil is full of root fibres. There is considerable doubt whether moisture is thereby conserved, and in many cases injury is caused by the rupture of root fibres.

J. R. B.

TOP-DRESS—Growing crops, particularly in early spring, frequently require an application of some quick acting and stimulating fertilizer. The application of such a fertilizer is known as top-dressing. It is usually necessary to top-dress crops after periods of severe weather, say spring frosts and cold rain, and after attacks of such pests as Wireworms, Frit Fly, Wheat Bulb Fly, and so on.

In some districts top-dressing means the application of some well-rotted dung or compost to a ley before ploughing.

TOWN REFUSE—See Fertilizers.

TRACTORS—See Horses *versus* Tractors.

TRENCHING—One of the greatest means of reclaiming soils is by trenching. Where the subsoil is very stony, trenching may have to be done by hand, which is very expensive. As a rule, however, it can be done by the plough. The object of trenching is to add to the depth of fertile soil by bringing up quantities of subsoil materials. The operation is quite distinct from subsoiling, where the subsoil is only broken and is not brought to the surface. Trench ploughing can be done by one plough taking a very deep furrow or by one plough following another in the same furrow. By the latter method it is possible to bring up an inch or two of subsoil for mixing with the top soil.

Trenching should be done in the autumn or early winter, so that any harmful substances which may be contained in the subsoil may be rendered innocuous by the winter rains and frosts.

TRENCHING, BASTARD—Bastard trenching is a favoured method of cultivating gardens and allotments. Compared with farm practice the effect is much the same as from subsoiling. Bastard trenching is done by opening out a trench about a foot and a half wide and one spade deep. The subsoil is then stirred about another foot, and on top of this the next spit of top soil is thrown. This procedure is continued until the whole area has been covered.

TULIP—See Bulb Growing.

TURBINES—See Water Wheels and Turbines.

TURKEY—See Poultry.

TURNIPS AND SWEDES—Introduction and Statistics—Contrary to popular ideas, turnips were known to the Greeks and Romans; they are referred to by Columella, who stated they were grown in Gaul, and used for cattle during the winter.

Coming to later times, the cultivation of turnips became an essential feature of agricultural practice in the Low Countries a long time before they received extended attention in England. The crop secured an enthusiastic champion in Sir Richard Weston, at one time (1591-1652) English Ambassador at the Dutch Court, who published the results of his observations on the agriculture of the Low Countries and thereby stimulated the cultivation of turnips amongst his own countrymen ("A Discourse of Husbandrie used in Brabant and Flanders, showing the Wonderful Improvement of Land there, and Serving as a Pattern for our Practice in this Commonwealth"; 2nd edit., edited by Samuel Hartlib, 1652).

Lord Charles Townshend (1674-1738) drew the attention of farmers to the merits of the turnip on his estate at Raynham in Norfolk. He showed that the four-course rotation improved the fertility of the soil and provided a means of fattening animals in winter; modifications of this system of farming spread gradually over the whole country. The cultivation of the turnip was greatly aided by the drill, invented by Jethro Tull (*c*. 1701), for previous to this they were sown broadcast. Swedes were introduced from Sweden in 1777, and, on account of their better feeding and keeping qualities, soon became very popular.

The acreages of turnips and swedes in the United Kingdom for 1925 ("The Agricultural Output of England and Wales," and *idem.*, "Scotland," *idem.*, "Northern Ireland"), and for 1930, were as follows:

	1925.	1930.
	Acres.	*Acres.*
England and Wales ..	806,000	671,300
Scotland	396,000	373,000
Northern Ireland	46,380	40,222

The decline in the area devoted to this crop in England and Wales was from 1,625,000 acres in 1871-75 to 843,000 acres in 1921-25. In Scotland in the same period the decline was from 504,000 to 396,000 acres, while in Northern Ireland it declined from 73,028 acres in 1847-56 to 51,480 in 1917-26.

Despite these substantial reductions, however, this crop continues to be one of the most widely diffused in all divisions of the United Kingdom, and, except in Northern Ireland, is, on the acreage basis, the most important root crop.

For England and Wales this is evident from Fig. 31, and by comparison with the corresponding figure under "Potato" it will be seen that the areas with a low acreage of turnips, viz., Lancashire, a portion of Lincolnshire, and Huntingdonshire, are characterized by a high acreage of potatoes. (See Agriculture, British Isles; Crop and Certain Other Statistics.)

Botanical and Varieties—Turnips belong to the Natural Order Cruciferæ. They are biennials, growing from a small seed, dark-brown or nearly black in colour. During the first year, the plant

TURNIPS AND SWEDES (*Continued*)—

accumulates reserve food material in the "root" (in reality partly hypocotyl and partly true root), which is a large, roundish bulb from the upper portion of which the leaves grow. In the second year, a strong erect stem 3 to 4 ft. high arises from the bulb, with lateral branches, bearing yellowish flowers, which eventually produce fruits (siliquas) each containing several seeds. (See Brassicæ.)

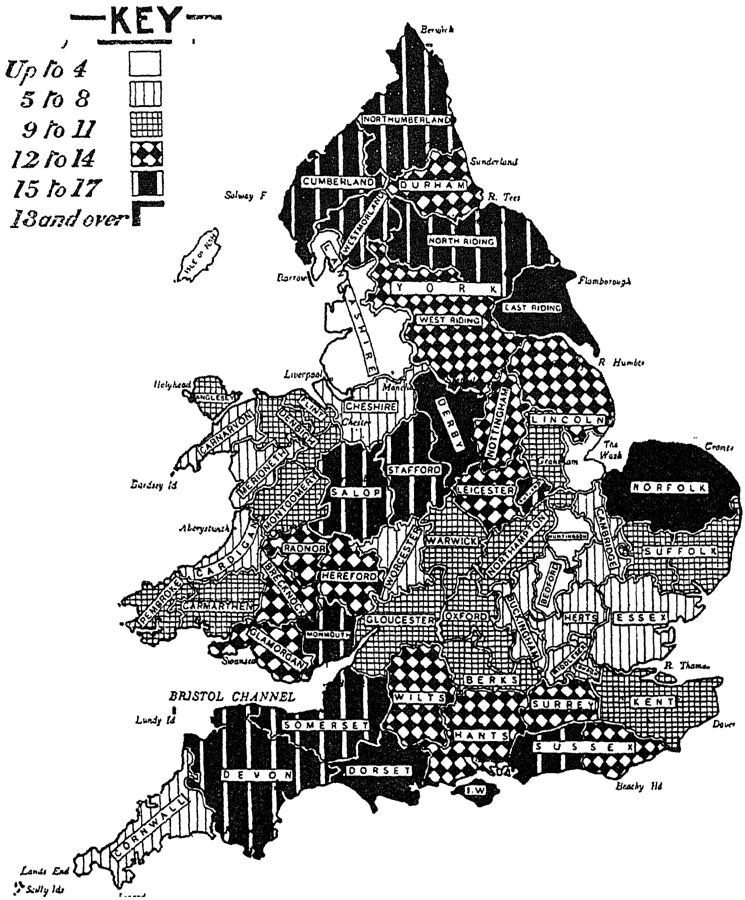


FIG. 31.—NUMBER OF ACRES OF FODDER ROOTS AND CERTAIN OTHER FODDER CROPS (TURNIPS AND SWEDES, MANGOLDS, KOHL RABI, CABBAGE FOR FODDER, AND RAPE) PER 100 ACRES OF ARABLE LAND IN 1925.

(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

Turnips may be divided into three classes: White Turnips, Yellow Turnips, and Swede Turnips.

TURNIPS AND SWEDES (*Continued*)—

White Turnips are white fleshed, but the colour of the outer skin varies, hence we have **White Tops, Green Tops, Purple Tops,** and **Greystones** (mottled green and purple). White turnips grow with great rapidity, but they contain usually only 7 to 8 per cent. of dry matter, which is less than that in other kinds. They are grown extensively for sheep feed, especially in England, both tops and bulbs being consumed in the field where they grew. When sown early, they are ready for use in the early autumn, whilst if sown late, they are consumed in early spring, and in a mild winter will continue to grow during the whole time they are in the ground. In the milder parts of England some varieties, for example, "six weeks" turnips, may be sown as late as September.

Hardy Green Round Turnips, sown in July or August, produce large quantities of feed in spring, the foliage being the most valuable part; they are known as "hardy greens," and are sometimes mixed with rape for sowing broadcast on stubble in late summer. The bulb is buried deeply in the soil, and is consequently protected from frost. As a rule, in a mild February any white turnips still unconsumed in the field begin to run to seed, but until the stalks begin to get woody they even then provide a useful sheep fold. When folding pregnant ewes upon turnips in spring, it is safer to run the horse-hoe under the roots a few days before using, to sever them from the soil. This results in a certain amount of wilting, after which they are a safer feed.

White turnips must be regarded as the most valuable sheep feed available for the winter months in those arable counties of England where sheep are folded on the land. Early and late sown white turnips are ready for use during practically the whole autumn and winter. The late date at which white turnips can be sown leaves ample time for cleaning the land, whilst owing to their rapidity of growth excellent catch crops may often be secured after any crop removed from the land in June or July. In a favourable season, in early districts in the South, "stubble" turnips may be grown after a cereal is harvested. Not only are white turnips invaluable for sheep, they are most useful for cattle, especially milking cows, the tops and roots being usually consumed together. The milk producer who has a small area ready for use in October or November will find the roots most useful. In addition to being invaluable for sheep, white turnips are most useful for cattle, especially milch cows, the tops and roots being consumed together usually. White turnips are also excellent for sowing on headlands of fields of mangolds, swedes, and sugar-beet.

Yellow Turnips—These, as the name suggests, are yellow-fleshed, and with 8 to 10½ per cent. of dry matter are intermediate in feeding value between white turnips and swedes. Amongst yellow turnips are included **Aberdeen Purple Tops, Aberdeen Green Tops, Early Sheepfold Green Tops, Fosterton Green Tops, Yellow Tankards,** and **Centenary** (an early maturing turnip). They are grown chiefly in the north of England and in Scotland, and are especially valuable for use earlier in the

TURNIPS AND SWEDES (*Continued*)—

autumn than swedes. At Cockle Park, in 1929, Favourite Purple Top Aberdeen gave a dry-matter yield of 2·26 tons per acre, with 27 tons per acre of roots containing 8·38 per cent. dry matter; Purple Top Mammoth, a soft turnip, with 2·54 tons of dry matter per acre from 32 tons 3 cwts. of roots containing 7·89 per cent. of dry matter, was the only turnip (as distinct from swedes) to exceed it in yield of dry matter per acre.

Swedes—Swedes may be divided into **Purple Tops, Green Tops,** and **Bronze Tops.** They require a longer period of growth than white or yellow turnips, from which they differ in the development of the stem or "neck," much firmer flesh, and a higher proportion of dry matter, usually from 10 to 13 per cent; they are also hardy and keep well into the spring. The proportion of dry matter, and hence the nutritive value, varies according to the locality in which they are grown; thus Lauder ("The Composition of Swedes," a report on the work of the Committee appointed to investigate the composition of swedes, *Scottish J. of Agric.*, April, 1926) showed that in this investigation roots grown in Aberdeenshire gave the highest, and those near Glasgow (Kilmarnock) the lowest percentage of dry matter, the roots grown near Edinburgh being intermediate in dry matter content between Aberdeen and Kilmarnock, except that in 1923-24 roots grown at a high elevation near Edinburgh corresponded closely in composition with the roots grown in Aberdeen.

In 1923-24 the average of all the varieties grown at Aberdeen was 14·10 per cent. dry matter, at Edinburgh 10·59 per cent., and at Glasgow 10·05 per cent. The superiority of dry matter content in the northern roots was mostly in the soluble solids: 11·17 soluble solids were found at Aberdeen, 7·72 at Edinburgh, and 6·95 at Glasgow. This confirms the generally accepted idea that roots grown in north-east Scotland are more nutritious than those grown in the south and west.

There are large numbers of varieties of swedes, and these have been studied from the point of view of their yield per acre and their composition.

Lauder (*loc. cit.*) showed that the differences in composition between varieties was greatest at Aberdeen and least at Glasgow.

He placed the varieties in four groups:

Group 1: Highest in dry matter—Kinaldie, Bargholm, and Inverquhomary types.

Group 2: Second in dry matter—Monarch and Best of All.

Group 3: Third in dry matter—Bronze Top (Globe) and XL All type.

Group 4: Lowest in dry matter—Bronze Tankard and Superlative.

Cockle Park Guide (1930) points out that the composition of swedes varies greatly with the season; thus, in 1904 20 cwts. of swedes had as much feeding value as 29½ cwts. in 1921—a corroboration of the generally accepted view that swedes appreciate a comparatively cool and fairly moist season.

TURNIPS AND SWEDES (*Continued*)—

The relative yielding power of the large number of varieties of swedes has been the subject of many tests. The National Institute of Agricultural Botany, Cambridge, conducted trials of types and varieties of swedes during 1926-29, and it is suggested that amongst the established varieties of the types tested Globe Bronze Top (Gatacre) on account of its high total yield and yield of dry matter and invert sugar was the most satisfactory of any tested. Semi-Tankard Purple Top (Superlative) was the heaviest cropper; it was somewhat poor in dry matter, but reasonably good in sugar.

Purdy's swede was only included in two reliable trials at Norwich, but showed very great promise (particulars supplied before publication by the courtesy of the Director of the National Institute for Agricultural Botany).

In 1929, the University of Leeds (*Bull.* 164) obtained the heaviest yield with Magnificent (Purple Top) at three centres out of six at which this variety was tested.

At Cockle Park in 1929, Darlington Bronze Top gave the highest yield of dry matter, 3·17 tons per acre, from 32 tons 14 cwts. roots containing 9·77 per cent. dry matter. Caledonian Bronze Top was second, with 3·06 tons of dry matter per acre from 27 tons 3 cwts. per acre of roots containing 11·27 per cent. of dry matter. Magnificent (Purple Top) was fifth in order of merit.

Milburn and Irons, reporting on trials in Lancashire from 1912 to 1919, state that Empire, XL All, and Ne Plus Ultra gave the highest yield, and Elephant and Lord Derby the lowest; Halewood and Magnum Bonum were comparatively free from Finger-and-Toe, the former, in addition, being the most resistant to Mildew of any of the varieties tested.

In Northern Ireland over a period of four years, 1926-29, at fifty-five centres, Magnificent gave the highest average yield with 30 tons 3 cwts. per acre, followed by Tipperary with 29 tons 4 cwts. For the three years 1927-29, Majestic and Masterpiece were included as additional varieties, and in the trials during this period (thirty-nine centres) Majestic gave the highest average yield with 30 tons 3 cwts., followed by Magnificent with 29 tons 3 cwts., Tipperary with 27 tons 17 cwts., and Masterpiece with 27 tons 12 cwts., per acre.

In the Irish Free State in 1925, at twenty-seven centres, Tipperary gave the highest average yield with 26 tons 19 cwts., of five varieties, followed by Magnificent with 25 tons 9 cwts. In 1926, at fifty-one centres, Magnificent was best with an average 26 tons 11 cwts., and Tipperary second with 26 tons 3 cwts. In 1927 at thirty-one centres Tipperary was first with an average of 27 tons 2 cwts., followed by Magnificent with 26 tons 9 cwts. ; Up-to-date gave 25 tons 7 cwts. In 1928 the varieties Tipperary and Magnificent again yielded well, and are thus evidently well suited to Irish conditions.

The high feeding value of swedes renders them especially valuable for fattening livestock, for which purpose they are very extensively utilized. Probably one-half the cattle fattened during the winter

TURNIPS AND SWEDES (*Continued*)—

months in Great Britain receive a daily ration of from ½ to ¾ cwts. swedes per head, and some receive larger quantities. For milch cows swedes are valuable, although not quite so useful as for fattening cattle. Both turnips and swedes are apt to give an objectionable flavour to the milk, although the danger of this is much reduced if the quantity fed is comparatively small and the roots are given to the cows after and not before milking.

Climate and Soil—Turnips and swedes succeed best in a cool, moist climate, such as that of Scotland, northern England, Wales, and Ireland. Swedes, especially, are a very hazardous crop in the south and even in the midlands of England, and in those districts it is only in a very favourable season that really heavy crops can be secured. Crops of 12 to 15 tons per acre of swedes are common enough in the south and midlands in a fairly favourable season, but in the more favourable climate of the north and north-west double this weight can be secured with comparative ease. The spells of hot and dry weather which frequently occur in the southern and eastern part of Britain in August and September result in the foliage turning blue and becoming mildewed.

Turnips and swedes are grown on a very large variety of soils, but as a fine tilth for the germination of the seed is important, they usually succeed best on light or medium soils containing an abundant supply of lime. Poverty of the soil in this ingredient usually results in trouble with Finger-and-Toe, especially in the case of swedes.

Position in the Rotation—Turnips and swedes occupy the root shift in the four-course rotation—roots, barley or oats, clover or "seeds," wheat. Where, as is often the case, this rotation is modified in various ways, they usually succeed a cereal, and are followed by a spring-sown cereal, which is often seeded with clover or rotation grasses. Occasionally, however, where they can be removed from the land in time they are followed by wheat.

Preparation of the Land—Turnips are a cleaning crop, and, given favourable weather, the long period between harvesting the previous cereal and sowing the turnips may be utilized for a very thorough destruction of weeds. This is especially the case in southern Britain, where harvest is earlier and the time of drilling the turnips later than in the north and west. In any district every opportunity should be taken to clean the land in autumn. The introduction of the tractor is a great help in this connexion, and some farmers now make a practice of taking a man off harvest work so that he may plough or cultivate the stubbles immediately they are cleared. There is no doubt that even in a wet autumn the ploughing of the stubbles immediately the crop is removed prevents the very considerable growth of weeds that takes place immediately the smothering effect of the corn ceases. In late autumn a second and deeper ploughing should be given, and in dry districts the farmyard manure is often ploughed in at this time. In heavy land districts, spring ploughing is often avoided, as it buries the winter mould and results in an

TURNIPS AND SWEDES (*Continued*)—

imperfect tilth. In typical swede-growing districts it is usual to plough and work the land in the spring as many times as is necessary to get rid of couch grass and other weeds. In such districts swedes are usually put in on the "baulk," "ridge," or "drill." These "drills" are prepared with the double-board mould plough, as for potatoes. After the land has been thoroughly cleaned the farmyard manure is put out into the drills, when they are immediately closed, and the seed drilled at once by means of a one- or two-row root seed-barrow.

In districts of low rainfall the land is thoroughly cleaned, but the seed is drilled on the " flat."

Artificial manure should be applied before the seed is sown, either in the drill or worked into the land on the flat. In some districts the seed and artificial manure are sown by means of a combined seed and manure drill.

Manuring—One of the most important points in connexion with the manuring of turnips and swedes is that the soil shall contain sufficient lime. If that is not so, the crop usually suffers severely from Finger-and-Toe, which may partially, or in some cases totally, destroy it. It has been shown at Cockle Park and elsewhere that the disease may be largely prevented by an application of lime; thus, the Cockle Park Guide, 1930, states that 2 tons of ordinary lime or 2 tons of ground lime applied once in a four- or six-course rotation will in the long run effectually check the disease.

As far as the general manuring of turnips and swedes is concerned Russell (" Manuring for Higher Crop Production," Cambridge University Press) points out that this depends to a great extent upon the climate, which limits the size of the crop in certain districts. If the climate will not on an average permit of a crop of more than 20 tons per acre, Russell considers that no amount of manuring will get over this difficulty. However, it is well to bear in mind that in the case of farmyard manure, phosphates, and potash, unutilized residues left by the turnips will remain over for the next crop. Climate also is not a constant factor, but varies greatly from year to year, and if the crop is under-manured, the yield in a favourable season will be limited from that cause. Manuring also depends greatly upon whether the turnips are grown as a major crop, as in the north where the climate favours them, or as a catch crop.

A considerable number of experiments has been conducted on the manuring of swedes. In Ireland, a series of tests was conducted over an extended period of years and at many centres. These tests show that under the climatic and soil conditions prevailing in that country, which are on the whole very favourable to the growth of swedes, a dressing of 10 tons of farmyard manure produced a large increase in crop, compared with no manure, but that a further dressing of 10 tons farmyard manure did not produce the same increase as the first 10 tons; its place could, indeed, be taken very effectively by a complete dressing of artificials. Thus, 10 tons of farmyard manure in conjunction with a comparatively small dressing of 4 cwts. of superphosphate per acre

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gave very good results. The addition of nitrogen and potash to the superphosphate gave comparatively small, but quite definite, increases.

Where artificial manures only are used, a complete manure appears to be more important, although phosphates even in this case are by far the most important ingredient in the mixture. Thus, in Ireland in 1904 the following results were obtained:

	Yield of Roots per acre. Tons.	Cwts.
No manure	4	9
4 cwts. superphosphate	20	7
4 cwts. superphosphate 1 cwt. sulphate of ammonia	21	18
4 cwts. superphosphate 1 cwt. sulphate of ammonia 3 cwts. kainit	24	18

Comparable results have been obtained in Lancashire, Aberdeen, and Durham, districts which are well suited to swedes. They show the supreme importance of phosphates. Small dressings of nitrogen and potash, however, give substantial increases, and occasionally the presence of a nitrogenous manure may save the crop by pushing the seedlings on, out of the reach of the Turnip Flea Beetle.

The great importance of phosphates is now generally recognized. During recent years phosphates from several sources have been placed on the market, and trials have been conducted to ascertain the most suitable kind to use. The West of Scotland Agricultural College arranged a series of trials to test this point in the years 1926-28 (see *Bull.* 117, 1929, by A. R. Nisbet).

The average yields of twenty-three trials in 1926-28 were—

	Tons per acre.
Superphosphate	26·04
Basic slag (11 per cent. P_2O_5 [high solubility])	24·84
Limphos (a mixture of superphosphate, mineral phosphate, and lime)	24·79
Basic slag (18·3 per cent. P_2O_5)	24·37

The most noteworthy feature of these trials, states the report, is the consistently outstanding position maintained by superphosphate. Ground mineral phosphate (120 mesh), in a series including forty trials over three years, gave 25 tons 18 cwts. as compared with 27 tons 19 cwts. from superphosphate. Each of the phosphatic manures used was applied in such quantities as to supply phosphoric acid equal to 6 cwts. of superphosphate (13·7 per cent. P_2O_5). In addition, a basal dressing of 1½ cwts. sulphate of ammonia and 1½ cwts. 30 per cent. potash salts was applied.

In the Irish Free State tests were conducted with and without farmyard manure (*Irish Free State Dept. of Agric. Report on Field Experiments*, 1927). With 15 tons per acre of farmyard manure the following results were obtained:

TURNIPS AND SWEDES (*Continued*)—

Phosphatic manures applied per statute acre.	*Average yield per statute acre,* 1927 (34 *Centres*).		*Average yield per statute acre,* 1926 (17 *Centres*).	
	Tons.	Cwts.	Tons.	Cwts.
No phosphates	21	2	21	4
Superphosphate, 448 lbs.*	26	14	24	19
Semol, 364 lbs.* (a mixture of equal parts of super- and Gafsa phosphate)	25	19	24	10
Gafsa mineral phosphate, 290 lbs.* ..	25	7	24	6
Ephos phosphate, 277 lbs.* (a proprietary mineral phosphate) ..	24	12	23	14
Clare phosphate, 279 lbs.*	23	8	23	7

* Containing equal quantities of phosphoric acid.

Without farmyard manure, but with a basal dressing of 1 cwt. sulphate of ammonia and 3 cwts. kainit per acre, the following results were obtained:

Phosphatic manures applied per statute acre.	*Average yield per statute acre,* 1927 (30 *Centres*).		*Average yield per statute acre,* 1926 (20 *Centres*).	
	Tons.	Cwts.	Tons.	Cwts.
No phosphates	10	15	11	9
Superphosphate, 448 lbs.*	24	8	21	19
Semsol, 364 lbs.*	23	4	21	10
Gafsa mineral phosphate, 290 lbs.* ..	22	7	20	9
Ephos phosphate, 277 lbs.*	21	16	19	8
Clare phosphate, 279 lbs.*	14	11	15	8

* Containing equal quantities of phosphoric acid.

These trials confirm the Scottish results and show that on the average superphosphate produces a heavier yield than the other forms of phosphate tried. In general it may be said that superphosphate, being highly soluble, stimulates the seedling plants most rapidly, and, provided the land is not lacking in lime, usually gives the best results.

Experiments in the West of Scotland (1900), Harper Adams Agricultural College (1909), and Devon County Council (1909) show that basic slag tends to produce a better quality of swede than superphosphate. Roots grown with slag usually retain their green leaves longer in the autumn, and ripen later than those grown with superphosphate.

On land that is deficient in lime, alkaline manures such as slag are preferable to acid manures such as superphosphate. The following manures are suggested as suitable for turnips and swedes, under average conditions, when grown in conjunction with a moderate dressing of farmyard manure. As a rule the higher quantities mentioned are suitable for those districts where climatic conditions are most favour-

TURNIPS AND SWEDES (*Continued*)—

able, such as Scotland, Ireland, Wales, and the north of England. Where no farmyard manure is available, the quantity of artificials should be substantially increased, and potash included in the mixture, except, perhaps, on the heaviest soils:

For soils containing sufficient lime—Dressings per acre:

(*a*) Heavy soils ..	½ to ¾ cwt. sulphate of ammonia or other nitrogenous fertilizer. 4 to 6 cwts. superphosphate. No potash to ¾ cwt. muriate of potash.
(*b*) Light soils ..	½ to ¾ cwt. sulphate of ammonia or other nitrogenous fertilizer. 3 to 6 cwts. superphosphate. 2 to 4 cwts. kainit.

On soils deficient in lime that substance should be applied in some form, if possible several months before the crop is sown. The quantity used will vary from 10 cwts. to 2 tons per acre of lump lime, or its equivalent, according to the sourness of the land. If lump chalk is available from 5 to 10 tons per acre may be used. (See Lime and Liming.)

(*a*) Heavy soils poor in lime	½ to ¾ cwt. nitrate of lime, nitrochalk, or calcium cyanamide (the latter worked into land at least a fortnight before drilling the seed). 5 to 8 cwts. basic slag (the quantity varying with the quality of the slag). No potash to ¾ cwt. muriate of potash.
(*b*) Light soil poor in lime	½ to ¾ cwt. nitrate of lime, nitrochalk, or calcium cyanamide (the latter worked into the land at least a fortnight before drilling the seed). 2 to 3 cwts. steamed bone flour or 3 to 6 cwts. basic superphosphate. 2 to 4 cwts. kainit.

Seed and Time of Sowing—In the best swede-growing districts of the north and west, it is usual to sow early in May, and even in the midlands the heaviest crops are usually secured by such early sowing.

In the south, swedes are not usually sown until June, whilst common or white turnips are sown in June, July, or even August. In a dry district, early sown swedes often suffer from Mildew in August or September, which may greatly stunt their growth.

The quantity of seed sown per acre varies to some extent in different districts; but as a rule 3½ to 4½ lbs. of swede seed, and 3½ to 4 lbs. of turnip seed per acre is sufficient. The larger quantities are used in Scotland and Ireland, especially for early sowing.

Given favourable weather, the seedlings make their appearance in a few days' time, especially if a good tilth has been obtained and there

TURNIPS AND SWEDES (*Continued*)—

is sufficient moisture in the land. There are few crops which require a finer and better tilth than turnips, and to secure this great pains are taken in the best turnip-growing districts. On heavy land, which is apt to form clods, a good tilth is sometimes difficult to obtain, especially after a wet winter followed by very dry weather in April and May. If the weather is dry, especially if the sun is hot and the wind cold, the seedlings are frequently eaten off by the Turnip Flea Beetle. In some seasons this insect does immense damage even where there was a good tilth. As a preventative, the seed is often soaked in turpentine or paraffin for two hours and then air-dried before sowing. This treatment tends to reduce damage from the beetle, although it is by no means certain in its results. It not infrequently happens that a second sowing has to be made, owing to the ravages of the beetle, but this also is sometimes destroyed by the insect. After drilling on the flat, the land is usually rolled. Where drilled in the baulk the one- or two-row drills used usually have a small roller following the coulter.

Spacing—" Chopping out " and " singling " is done after the plants are in the " rough-leaf " stage. In some districts the thinning is done by workers on their hands and knees, but in most parts of England it is done by the hoe, the 7-in. blade being probably the most suitable size to use.

An experiment conducted by the West of Scotland Agricultural College indicated that 10 inches between swedes and yellow turnips in the rows was the best distance, a heavier crop being obtained with this distance than with either 8 or 12 inches. Experiments in Lancashire and at Holmes Chapel gave best results with 6 and 9 inches, respectively.

In the case of white turnips the distance apart of rows and the distance from plant to plant depends to a great extent upon the time of sowing, late-sown turnips requiring less room, as they cannot be expected to grow so large as those sown early, and this is also, no doubt, true with swedes.

Turnip-thinning machines are sometimes used. They are of use in a perfectly regular crop, but where the " plant " is not perfect they are not satisfactory, as they do not make due allowance for gaps. In the case of very late sown white turnips, the crop may even be left unsingled, and merely harrowed across the rows; crops treated in this way not infrequently produce small turnips suitable for culinary purposes.

After-Cultivation—In the case of the crop grown in rows in the ordinary way, horse-hoeing is performed before singling. The number of horse- and hand-hoeings necessary after singling depends to a considerable extent upon the weather, the amount of rubbish present, and upon the date of sowing. It is a good practice, however, to horse-hoe several times in the case of a crop sown in May or June, as this tends not only to destroy weeds, but also to conserve soil moisture. If desired the roots may be moulded up after the last horse-hoeing, as this pro-

TURNIPS AND SWEDES (*Continued*)—

tects them to some extent from frost. In the northern parts of Britain and in many parts of Ireland cultivation between the rows is usually performed by a one-row drill grubber or one-row horse-hoe.

The details of cultivation of turnips and swedes differ rather considerably in different districts, much depending upon whether the crop is grown on the baulk or ridge, or on the flat. In the former case the cultivation more resembles that given to potatoes; in the latter it closely resembles that given to mangolds and sugar-beet in southern and eastern England, horse-hoes being used taking several rows.

Lifting and Storing—When the crop is to be consumed by sheep in the field in which it is grown, it may be left untouched until required.

This plan is, however, only safe in the milder parts of the British Isles, as in a severe winter most of the crop may be spoiled. This was strikingly shown in an experiment conducted by Dr. Jameson in Aberdeenshire during a very severe winter. In this case the untouched crop was entirely spoilt by the end of March. In another portion of the field, where the roots were earthed up in the rows 83 per cent. decomposed. Where a furrow was opened, two rows pulled and the roots placed in the bottom of the furrow, the soil being ploughed back over the roots, leaving the tops above the ground, 28 per cent. decomposed, whilst where the roots were pulled, topped and tailed, and put in heaps of 1½ cartloads and covered with 4 ins. of soil, only 6 per cent. were decomposed by the end of March. The latter plan is quite commonly adopted where the roots are to be fed to sheep on the field where they are grown.

In the case of early sown white or yellow turnips, ready for use in early autumn, there is no necessity for storing; they are either folded where grown, to sheep, or carted off and fed, tops and roots together, to cattle, either on grass or in the cowshed. Swedes, on the other hand, are usually stored and protected from the frost in some way, as they are generally required for use rather later in the season. Before carting they are topped and tailed, four rows being placed together for convenience in carting. The work is usually performed by hand, a strong knife being used for the purpose.

The roots may be stored in:

1. Small conical or pyramidal heaps, uniformly distributed over the field. The heaps are covered with straw and 4 to 6 ins. of earth.
2. Larger heaps in the form of pyramids covered with straw and earth.
3. Long clamps, covered with straw and earth. These may be adjacent to the homestead near where they are required for cattle. Sometimes the roots are placed in a shed, or against or between stacks, or against banks, where they will be protected from the north and east. They are then covered with rough grass, hedge-side trimmings, or stackyard waste. This simple method of protection is much less expensive, and often quite as effectual as straw and earth. Much depends upon the amount of shelter available, a comparatively

TURNIPS AND SWEDES (*Continued*)—

light covering being necessary when the shelter from the north and east is good.

Yield—The average yield of turnips and swedes in Great Britain and Ireland is about 15 tons per acre. This, however, is much smaller than can reasonably be expected in a district which is really suitable for growing the crop; in fact, in northern and western districts and in Ireland crops of 30 tons of swedes per acre are comparatively common. In the southern and drier districts, swedes are a very hazardous crop, and very small yields, 10 tons per acre or less, are common; in fact, in such districts it is doubtful whether they are worth growing. In the drier parts of Britain, white turnips are commonly grown as a catch crop, after a previous crop such as trifolium, rye, or tares, folded by sheep or removed. When so grown the total weight of the turnips, roots, and tops together may be 15 to 20 tons per acre in a favourable season, but often it is less. In this case, however, a large yield cannot be expected.

Keeping Qualities—The keeping qualities of white turnips depend to a great extent on the time of sowing. When sown early, they should be consumed in the autumn, and even then occasional roots will rot. When sown late in the season, say in August, they will stand a considerable amount of frost and will keep, in a normal winter, until spring, when they begin to run to seed. Aberdeen and Yellow soft turnips are usually sown fairly early, and often do not keep very well; they should be used in autumn.

Swedes differ in keeping qualities according to variety and time of sowing, late-sown roots keeping best. Purple tops do not usually keep as well as green or bronze tops; hence they should be used first. Unless they are exposed to severe frost, swedes will keep fairly well until early spring.

In those districts where mangolds are grown extensively swedes are used first, and mangolds later in the season.

Seed Production—The production of seed of valuable varieties is largely in the hands of seedsmen, who devote great pains in the selection of strains in which the dry matter content, the shape, texture, top, neck, and other points receive careful consideration. Selected roots are pitted for the winter and planted in spring, about 3 ft. apart, each variety being some distance from any other cruciferous crop grown for seed, to avoid hybridization. (See Brassicæ.) The stock seed so obtained is distributed amongst selected farmers, who sow it in July or August, broadcast or in rows. The small plants are left where sown until February or early March, when they are transplanted into rows 28 inches or so apart, the plants being placed 1 foot apart in the rows. The land is horse- and hand-hoed as long as growth permits. The leading shoot of the runners is nipped off to induce abundant side growth. When ripe, usually at the end of July, the crop is cut by means of hooks, and laid in sheaves, which are carted when dry, bags and canvas sheets being placed in the carts and against the stack to reduce loss of seed.

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Sometimes, especially in the case of white turnips, a late-sown crop is merely allowed to remain for seed where growing, without transplanting. The crop may be cut with the binder or side delivery reaper, and shocked in the same manner as corn.

To avoid loss of seed, a crop harvested by machinery should be cut when slightly green, and in the early morning, while dew is on the crop. The crop is thrashed with the ordinary thrashing machine, and a good crop of turnip seed is from 7 to 10 cwts. per acre. Most of the seed grown in Great Britain is produced in the south-eastern counties of England.

A. W. O.

INSECT PESTS OF ROOT AND FORAGE CROPS—Root crops appear prone to suffer in a more spectacular, observable, or wholesale manner from insect pests than forage crops, a condition due partially to the manner of growth and cultivation. Swedes, mangolds, etc., are usually sown in a regular manner and definitely spaced; later the young plants are "singled," leaving a relatively small number of individuals to occupy the ground, and grow to a maximum size. These relatively few individual plants are exposed, therefore, to the combined attack of such insect pest populations as may be present, and the resultant injury tends not only to be more concentrated in consequence, but to be more readily observable, and the death of any plant produces a gap which cannot be adequately filled. The forage crops, on the other hand, are intended to occupy the whole available space, and produce the maximum amount of leafage. Here, then, we have a much greater number of plants of a type which can more readily replace foliage losses, and the total loss of even a number of plants may pass unnoticed; losses must be severe before their existence is apparent. It may be noted, further, that (1) swede, turnip, rape, kale, and mustard are Cruciferæ; (2) the clovers, sainfoin, lucerne, vetches, and gorse belong to the Leguminosæ; (3) carrot and parsnip are Umbelliferæ; (4) maize and the cereals generally, Gramineæ; and that each of these plant groups has its own attached group of insect pests. Certain of these insect groups are, in some measure at any rate, common to both the root and forage categories, and may be considered together.

The chief pest groups may now be considered in brief:

Collembola, commonly called "Springtails," small, primitive, wingless insects, are frequently present in enormous numbers, and from time to time damage by one or another of these may be reported, whilst two are particularly noxious. *Bourletiella hortensis* Fitch causes minor leaf damage to mangolds, and is also one of the chief causes of " strangle " in young plants of this crop, which are nibbled at about soil level, subsequent growth bringing about constriction at this point, and finally resulting in fracture (W. M. Davies, *J. Min. Agric.*, xxxiv., 4, July, 1925). The same writer has studied the leaf injury of clovers due to *Sminthurus viridis*, another of these Springtails (*Bull. Ent. Res.*, xviii., 3, February, 1928).

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The common green Capsid Bug, *Lygus pabulinus*, has a very wide range of host plants and is responsible for increasingly widespread injury; it has been studied recently (F. R. Petherbridge and W. H. Thorpe, *Ann. App. Biol.*, xv., 3, August, 1928). The writer has recently investigated severe injury to sugar-beet due to immature forms which had migrated from nearby hedges (C. L. Walton and L. N. Staniland, *J. Bath and West. Soc.* iv., ser. 6, 1920).

Very numerous species of Aphides are amongst the most serious enemies of both root and forage crops. Of special note is *Aphis rumicis* L., generally known as the Bean Aphis and found extensively on mangolds, to which it migrates from weeds. The bionomics of this insect has been the subject of extensive studies in recent years (J. Davidson, *Ann. App. Biol.*, and elsewhere) whilst general information may be sought in a recently completed monograph ("British Aphides," by F. V. Theobald, Headley Bros., 3 vols., 1926-27-28). Brassicæ are seriously infested by *Brevicoryne brassicæ* L., and vetches and clovers are attacked by several species, notably *Megoura viciæ* Kalt. (on vetches), *Myzus persicæ* Sulz., *Anuraphis warei* Theob., and others on clover (see J. R. W. Jenkins, *Welsh J. Agric.*, 1926-29, for clover pests in general).

Lepidoptera—The larvæ of the cabbage white butterflies are well-known enemies of brassica foliage, and may now and again attack swedes as well as the cabbage group: *Pieris brassicæ* and *P. rapæ* are the chief offenders. "Cutworms" or "Surface Caterpillars," the larvæ of a number of "Noctuid" moths, notably *Euxoa segetum* and *Feltia exclamationis*, may be very destructive; working at or just below the surface, they eat away the roots and stems, causing havoc to turnip and mangold, more especially when July is hot and dry.

One of the chief pests of swedes, turnips, kale, etc., is the little Diamond-back Moth *Plutella cruciferarum* Curtis, whose tapering green larvæ swarming on the underside of the leaves may literally cut these crops to pieces (Leaflet 22, *Min. Agric. and Fish.*) during the period the end of July, August, and September.

Coleoptera—Amongst the beetles are a number of troublesome enemies, notably *Atomaria linearis* Steph., known as the Pigmy Mangold Beetle, and three "chafers," particularly the large grub of the Cockchafer *Melolontha vulgaris* L. Wireworms are very serious pests and are the tough, yellow, soil-inhabiting, root-feeding larvæ of various species of beetles of the genera *Agriotes* and *Athous*. Even more numerous in species are the little Flea Beetles and their larvæ. The adults migrate from their natural Cruciferous and Polygonaceous host plants to destroy sowing after sowing of seedling turnips, swedes, etc.; their larvæ also injure leaf and root to some extent. The chief genera are *Phyllotreta*, *Chætocnema*, and *Psylliodes* (for recent work see H. C. F. Newton, *J. S.-E. Agric. Coll. Wye*, July, 1928 and 1929). Another genus with a number of species is *Sitona*, the adults of which are destructive to the foliage of clovers and the other leguminous crops, whilst the larvæ feed on the roots and may thus injure the

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bacterial "root nodules" found thereon. (See D. J. Jackson, *Ann. App. Biol.*, June, 1922.)

The Cabbage Gall Weevil, *Ceutorrhynchus pleurostigma* Marsh, causes "galling" on the stems of Brassicæ, and also on swede and turnip, within which the larvæ feed. This pest, although unsightly, seldom seems to do serious damage on otherwise healthy crops, and is apparently negligible on root crops.

Minute weevils of the genus *Apion* injure clovers, the adults feeding on the foliage and the larvæ in the flowerheads or on the young ovules also (also some in the stems); the losses in seed may be considerable (J. R. W. Jenkins, *Welsh J. Agric.*, v., 1929).

Amongst **Diptera** (flies) may be mentioned *Contarinia nasturtii* Kieff., the Swede Midge, the minute larvæ of which feed upon and either destroy or distort the growing point, or cause characteristic crumplings of the foliage (T. H. Taylor, *Dept. Agric. Leeds Bull.* 82, 1912, and C. L. Walton, *J. Min. Agric.*, September, 1927). The small orange and yellow larvæ of various midge species attack leguminous crops, no less than eleven being listed as British (H. F. Barnes, *J. S.-E. Agric. Coll. Wye*, July, 1927), the most abundant being *Amblyspatha ormerodi*, Kieff, which causes the withering and death of red clover, also *Dasyneura leguminicola* Lintner, which prevents seed formation.

The larvæ of *Chortophila brassicæ* Bché., the Cabbage Root Fly, may at times cause injury to root crops, and *Pegomyia hyoscyami* Panz. (*betæ*) is a well-known pest of mangolds and sugar-beet. The brown, hairy fly lays its eggs beneath the leaves of the seedling plant, the larva burrowing within the tissues and causing marked blistering; parsnips may also suffer to some extent.

The Carrot Fly, *Psila rosæ* Fab., is the chief pest of the crop, the larvæ tunnelling in the root; it will also attack parsnips.

In addition to those major insect pests enumerated there are many others of significance in relation to the crops under consideration, some of which may be of real importance in certain years, or in prescribed localities only; others may be of constant appearance, but seldom serious, whilst others again will be normally scarce, or negligible: *Blitophaga opaca*, the Carrion Beetle on mangolds; *Helophorus rugosus* and *H. porculus*, the Turnip Mud Beetles on crucifers; and *Pionea forficalis*, the Garden Pebble Moth, may be cited as examples.

Fluctuations are usual in all insect pests, and much remains to be learned as to the interaction of natural environmental factors—weather conditions, abundance or otherwise of predatory enemies, parasites, etc. —and of the action of crop fluctuations due to the exigencies of supply and demand, etc.—in other words, biological and economic factors. It may be said, however, that some little progress has been made in the ability to forecast the probable incidence of certain pest insects. Meanwhile, the farmer or grower cannot afford to ignore the available and constantly increasing methods of protecting his crops, by destroying injurious insects or avoiding their attack. It is obvious that practically every part of a plant—root, stem, leaf, seed, etc.—is liable to

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attack at various stages in its life history, and that the losses due to insects are generally far greater than is realized by the majority of growers; these may indeed be of such an extent as to make the difference between profit and loss, even when the attack has not reached the point at which it is the obvious cause of failure.

Means of Control—In the case of the crops under discussion in particular, difficulties often arise when the question of pest control is considered, partly on account of the size of the areas to be treated, and frequently owing to the cost of such treatment in relation to the value of the crop. Methods such as spraying or dusting, which might be quite successful, and are in full use by fruit growers, gardeners, and growers of crops of relatively high value, may be uneconomic in the case of root crops or, say, clovers, especially when grown in large breadths. Furthermore, the machinery necessary for spraying, etc., is seldom available, more particularly on the smaller holdings. Whilst, therefore, these methods must be considered and used, where economically possible, the farmer is more likely to prefer *preventive* methods as exemplified by rotational or selective croppings, resistant varieties, and cultural methods. Correct soil management, good systems of manuring and of cultivation, etc., are of the greatest importance, for sound health is of the highest importance in maintaining crops free from insect injury. Clean culture cannot be too highly stressed, since weeds are one of the chief causes of the presence of many major insect pests; this is particularly so in the case of cruciferous crops, whose insect enemies—Aphides, Diamond-back Moth, Flea Beetles, Swede Midge, and many others—are maintained on rough land, in hedgerows, and even in the crops themselves, from year to year, in readiness to multiply at the appropriate time.

The arrangement of rotations so that crops of the same family do not recur too frequently on the same ground, or in too close proximity, is of importance, and in certain cases the selection of an earlier or of a later maturing variety, or an earlier or later date for seeding or planting, may have the effect of removing the crop beyond the usual date of oviposition of a particular pest, thereby ensuring escape, or greatly minimizing the risk of infestation.

Correct soil conditions and opportune plant stimulation, by maintaining continuous growth and free leaf production, may do much to minimise and tide over attack, as, for example, with the various flea beetles, mangold fly, and others.

Under " cultural methods " are included such operations as rolling with the object of crushing and thereby checking such soil larvæ as Leather Jackets and those of the Mangold Fly. " Trapping " by means of sticky surfaces may sometimes be employed successfully, as also the use of trap crops, which can be destroyed or turned in after use. The employment of resistant crops—such as mustard where Wireworms are known to be prevalent, and turnips where Swede Midge occurs—may also be considered. (For many points of practical detail see " Insect and Fungus Pests of the Farm," by J. C. F. Fryer and F. T. Brooks, E. Benn, Ltd., London, 1928; also " Agricultural Ento-

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mology," by D. H. Robinson and S. G. Jary, Duckworth and Co., London, 1929.)

From amongst remedial measures may be mentioned poison baits, which with due precautions may be most effectively used to control Leather Jackets, Cutworms, Slugs, Millipedes, etc. The most usual form of poison bait consists of 1 lb. of Paris green mixed thoroughly with 30 lbs. of bran or thirds, and moistened with 2 quarts of water. This amount is broadcast over 1 acre of land and is most effective if applied during warm, moist weather (*Bull. West Scot. Ag. Coll.*, 103, 1925). Sodium fluoride has also given promising results, applied as above—1 lb. to 20 lbs. of bran (H. W. Thompson, *Welsh J. Agric.*, iv., 1928). (See Insecticides and Fungicides; Insects, Measures of Controlling.)

Another useful remedy which can be effectively used as a repellent and preventive of egg-laying is naphthalene. It can be either worked into the surface soil or broadcast lightly through the crops from time to time. A useful form for this purpose is that sold as " whizzed," which may be applied at the rate of ½ to 1 oz. per square yard. There are numerous references in literature, a recent one being L. N. Staniland and C. L. Walton, *Ann. Rept. Agric. and Hort. Res. Stat.*, Long Ashton, Bristol, pp. 103-5, 1928.

C. L. W.

UREA—See Fertilizers.

VEGETABLE BREEDING—Up to the present time the amount of scientific research which has been carried out on the breeding of cultivated vegetables is surprisingly small; in fact, compared with the mass of literature dealing with the genetics of the cereal crops, the records of experimental work on vegetable breeding are almost negligible in quantity; though it must not be forgotten that Mendel carried out his most important work on the garden pea.

It is, of course, not difficult to understand why cereals should have had a prior claim to the plant breeder's attention, for they form the staple foods of the human race, whereas market-garden crops are as often as not regarded as luxuries, at least in this country. The improvement of vegetables, therefore, has not been stimulated by the same degree of urgency as the improvement of cereals.

There is probably another reason why vegetables have been neglected by geneticists. Qualities of economic value, qualities which are of importance in the market, such as whiteness and texture of curd in broccoli; solidity, size, and colour of head in cabbage and lettuce; earliness, keeping qualities, and so on, in the case of other vegetables, have only been attained by centuries of continuous selection. The mode of inheritance of the characters involved in these economic qualities is not known, and an investigation of only a few of them might well afford material for a lifetime of study. It is, in fact, a far cry, as a rule, from the simple characters usually dealt with by geneticists to the complex range of qualities which may give a vegetable not only its value as a food but its superiority in the market over others of similar type.

VEGETABLE BREEDING (*Continued*)—

Yet somehow, and without the aid of the scientific plant breeder or the disciple of Mendel, cultivated vegetables have reached a state of development which is in many cases astonishing. For not only do many of our vegetables possess the more obvious qualities from which they derive their value as food, but they possess the very much less obvious points desired by the grower or by the salesman. We have, for instance, not merely cabbages, varying in size from Tom Thumbs to varieties producing heads of many pounds weight; utilized for stock feeding; cabbages of different colour, from the pale glaucous green of the Copenhagen market to the deep green of Winningstadt, or the magenta of the pickling varieties; cabbages of different shapes; flat, round, conical, or oval; quick or slow growing cabbages; cabbages that are almost frost-proof, others that are unable to stand the frost; cabbages that are suitable only for spring sowing; cabbages which must be sown only in the autumn; and so on. There is, in fact, a mass of material in our market gardens, which, superficially at any rate, bears little resemblance to the wild plants from which it has evolved. Even the least imaginative of men must feel a certain amount of surprise when he compares plants of Roscoff broccoli, Erfurt cauliflowers, Brussels sprouts, or red pickling cabbage, with their wild prototype which is still to be found growing on some portions of our sea-coasts.

Incredible as it may seem, these developments have been brought about in the simplest possible fashion. There is an old saying to the effect that no two plants are exactly alike. We do indeed set up an arbitrary standard which we call a species, or a biotype, or a variety, but on either side of this standard we encounter numberless variations. In the case of cultivated vegetables what has happened is that for generation after generation observant gardeners have marked down and propagated the variations which seemed to them to have most economic value.

It is often loosely asserted that improvements in vegetables have been caused by selection. Selection, however, has caused nothing. The variation is produced by the plant, and man merely utilizes for his purposes the material he finds ready to hand. It is worth while remembering that the sort of variation that we value, such as the mass of aborted flower-buds in a cauliflower, or the bloated terminal bud of a cabbage, would have little chance of survival outside a garden. Our most prized varieties are in fact monstrosities which can only survive in special conditions.

Some vegetables—an instance is the garden pea—have been in cultivation so long that their wild prototype is not known; their history is lost and their origin obscure. But in one case the history of the cultivated vegetables appears to be known with certainty; this is the case of the population of plants which are grouped under the name of the "Student" parsnip. Parsnips were known, cultivated, and eaten by the ancient Romans, but the "Student" dates back no further than 1847. In that year, Professor Buckman of the Royal Agricultural College, Cirencester, collected the seeds of wild parsnips which were growing in the neighbourhood of the College. These seeds

VEGETABLE BREEDING (*Continued*)—

he sowed, and from the resulting plants he commenced selecting individuals which varied in the direction of improved size and quality of root. This method was extraordinarily successful, for a photograph of the Student parsnip taken in 1903 (the twenty-eighth generation from the wild plant) shows a root of good appearance, equal in size to the best cultivated parsnips of more ancient lineage. A similar experiment was carried out successfully with carrots by Vilmorin in 1832.

It will be noted that both the carrot and the parsnip belong to the family Umbelliferæ. No evidence of a like nature is available in the case of other botanical families. So far, no one has raised broccoli direct from the wild cabbage, nor marrowfat peas from any Pisum species by the method of Buckman and Vilmorin.

Variations from type have been mentioned. It is suggested that these are mutations, hybrids between mutations and the type, or hybrids between mutations. They are the material used by plant breeders, both pre-historic and present-day, in their efforts to raise improved or altered vegetables. It is probably that stable hybrids appear from time to time: plants, that is to say, which would breed true if fertilized with their own pollen. But, under primitive conditions of seed-growing, plants are almost invariably crossed freely by other types; and even under present-day commercial conditions a similar state of affairs is nearly always the rule. As a result, and quite apart from the innate variability of plants, we must regard most varieties, strains, or stocks of vegetables as collections of types which differ slightly or markedly from one another. In dealing with vegetables, especially those which are raised from seed and are normally cross pollinated, one soon loses the concept of a " variety ": what replaces it is a mental picture of a mass of individuals approximating more or less closely to a given standard. And every time a selection of such plants is grown for seed a fresh crop of hybrids is produced. Therefore, if a stock is to be prevented from deteriorating, a fresh selection of desirable plants is necessary at frequent intervals. It is, in fact, only by rigid and continuous selection that commercial stocks can be kept up to the mark. Obviously this entails an enormous amount of work on the part of highly trained men; and it follows that the larger the scale on which seed is grown the more difficult becomes the task of selection and the less likely is it to be effectively carried out.

At Cambridge over 300 stocks of onions have been tested, and in no case was it possible to describe one of them as a definite variety, for each contained many types, some worthless, some valuable. It is, in fact, possible to purchase a packet of onion seed of a named variety supposed to be straw-yellow in colour, globular in shape, and suitable for spring sowing, which will give a crop of bulbs varying in colour from magenta and deep mahogany, through various shades of brown and yellow, to pure white; and varying in shape from oval to flat. The same stock will probably contain bulbs that ripen at the normal time, together with a percentage of thick-necked bulbs which do not ripen at all; there may also be a percentage which rot away in a

VEGETABLE BREEDING (*Continued*)—

few weeks as a result of attack by the fungus *Botrytis allii*, while others appear to be immune to the attack of this fungus.

Similarly with Brussels sprouts: there is usually in a commercial stock obtained from a reputable firm a small percentage of plants which are of good type. But there is also a percentage of plants which cannot be described as Brussels sprouts at all, since they are hybrids with other Brassicæ, such as broccoli, cabbage, or even kohl rabi. Among the genuine sprouts are to be found plants of all types, from those which produce minute sprouts the size of a pea, to those producing large open rosettes of leaves quite useless for market purposes. Some of the plants produce sprouts which are not firm enough; others may be firm, but rough and of bad appearance, or of a pale colour. Again, there are types with only half the stem furnished with "buttons"; others with the buttons so widely spaced that the plants cannot possibly be profitable. In fact, in most stocks no two plants are alike. It is worth while remembering that all the plants, good and bad alike, occupy the same space and are equally expensive to grow.

In view of this state of affairs it is not surprising that many market gardeners, whose living depends on the quality of the stocks they produce, employ every effort to grow their own seed from selected plants, or to obtain seed from a specialist grower.

Methods of Breeding—The simplest of all methods of plant breeding is one which in all probability has been practised since pre-historic times: the saving of seed from desirable plants. From the progeny of such plants further selections are made, and seed is again saved from these selections. A refinement is the isolation of the selected plants so that they may not be crossed by inferior types.

This method is, of course, still widely practised, and its results are undeniably good, provided that the requisite degree of isolation is obtainable. In some cases where a large quantity of seed is required for sale, two selections are made; one of these consists of a few plants of the highest quality, while the other is made up of a large number of plants which, though good, are not up to the high standard of the smaller selection. The seed from the highest quality plants is retained by the grower, sown by him, and from the resulting crop he again makes his selection for future seed production, whilst the good but not super-excellent plants produce the seed that is intended for immediate sale.

There are, of course, certain difficulties attending this method: there is the practical difficulty of obtaining isolation for the flowering plants (and this difficulty is almost insurmountable in a seed-growing district). And there is a genetic point worth bearing in mind: the desired type selected each year by the grower may be an unstable type which cannot be fixed, and in this case selection may go on for an indefinite period.

An examination of a stock of Brussels sprouts which has been selected continuously for over forty years shows that a high percentage of desirable plants of varying types is present; there are no off-types resulting from out-crosses, nor any types which are the legacy of such out-crosses. On the other hand, undesirable types are still present, and on the whole the stock is not so good as stocks resulting from

VEGETABLE BREEDING (*Continued*)—

five years of plant breeding on more intensive lines. It could be said definitely, however, that this long-selected stock was much superior to the average commercial strain raised by ordinary seed growers' methods.

A more modern and more rapid way of breeding differs from the above in the fact that seed is saved from each selected plant and sown separately. Selected plants are only drawn from the best culture or cultures, and seed is again saved from each separate plant. With this method there is a rapid weeding out of undesirable parents, and in the end it is possible to reach a high standard of quality and purity. Even with this method, however, the work of continuous selection cannot be evaded.

It is obvious that the " personal element " enters very largely into plant breeding. An observant eye which has been much practised and highly trained is, in the first place, essential, and without it effective selection is not posssible. And it is clear that in very few cases is it likely that two selectors will have the same views as to what constitutes the perfect plant; hence the material selected for propagation by one breeder will not be the same as that selected by another. Therefore, since we must conceive each vegetable as being not one fixed and definite type, but a collection of types, each breeder will eventually evolve from his original material a stock conforming to his own standard.

The two methods of improving vegetables which have just been described are effective, but neither is exact nor rapid enough for the modern plant breeder. It is desirable to know as much as possible about the genetic constitution of the material which is being used for breeding purposes if it is to be manipulated successfully. Selected plants are therefore selfed, that is to say, insects are excluded from their flowers and these flowers are fertilized with their own pollen. In some cases, where a plant is homozygous (see Mendelism) for the desired characters, it will breed true at once, and if otherwise satisfactory can be used for seed production. Such cases are rare in cultivated vegetables, and, as a rule, segregation of characters occurs. Further selection and further selfing may then be necessary.

Certain vegetables, notably Brussels sprouts, are as a rule self-sterile, that is to say, they will not produce seed when fertilized with their own pollen; consequently a different mode of attack is necessary. Two plants resembling each other as closely as possible may be crossed together and their progeny used as a basis for further work.

By these two methods information is obtained as to the genetic make-up of the material used, and, in addition, some idea as to the mode of inheritance of the various factors. In short, by selfing, crossing, and observation of the character of individual plants of a mass selection the plant breeder acquires a knowledge of the potentialities of his material.

To gain exact information as to the mode of inheritance of the different characters of a plant, carefully planned experiments lasting many years and, in the case of certain vegetables, occupying a large

VEGETABLE BREEDING (*Continued*)—

area of ground would be necessary. Obviously, to obtain the best results in plant breeding, exact information concerning the genetic constitution of the material used is essential; but it is equally obvious that it will be a very long time before such information is available, and that in the meantime selection and a common-sense application of Mendelian principles must be relied upon to give results of practical and economic value. A plant breeder by careful observation of his material when grown in mass selection, crossed, and selfed, is enabled to make deductions which, although he may have neither time nor space to verify them statistically, are of the utmost value in his work.

As an instance of this, the case of onions may be taken. During the course of work at the Cambridge Horticultural Research Station hundreds of plants have been selfed and their progeny examined. The plants used had bulbs varying in the following characters: shape, size, colour, time of maturity, and keeping quality.

Considering the question of shape first: all shapes were encountered, from thin, flat onions to semi-flats, oblates, spheres, and ovals. One fact of importance was evident from the start: no flat onion when selfed had among its progeny onions of oval or globular shape. On the other hand, the progeny of most of the selfed globular onions contained a range of shapes from flat to globular. Here, at the outset, is an explanation of the fact that in the case of a strain of globe onions grown for seed purposes by the method of mass selection there is nearly always a percentage of flats and semi-flats, and a possible explanation of the fact mentioned by Vilmorin that the Danver's Yellow Globe Onion "when first introduced into France (about 1850) was quite spherical in shape, but now it grows almost always more or less flattened not only in European gardens, but also in its native country." It is clear that, to build up a strain of onions of globular shape, every bulb used must be tested; for there are globes which breed true, and globes which cannot be distinguished by their external appearance from true-breeding globes, but which give in their progeny a variety of shapes. Mere selection by shape is, therefore, not sufficient, for in a mass selection there is bound to be a large number of bulbs which are heterozygous for shape.

The question of size is complicated by cultural factors. An onion may only weigh ½ oz. because it has been poorly grown (as in the case of onions grown for "sets"). But experiments show that whereas the progeny of certain bulbs never exceed 2 ozs. in weight, the progeny of others (grown in as far as possible comparable conditions) reach 12 or 16 ozs. Size, then, is also a character which can be dealt with on Mendelian lines.

Similar facts emerge in connexion with colour; that is to say, onions of certain colours may either breed true or they may show in their progeny a range of colours. A salmon-coloured bulb may give a series of colours ranging from deep salmon to yellow. And from the range of colours so obtained it is possible to extract true-breeding salmons and true-breeding yellows, and a collection of intermediate colours which never breed true.

VEGETABLE BREEDING (*Continued*)—

The progeny of certain of these selfed bulbs ripened off early, in other cases there was a mixture of earlies and lates, and at the other extreme, cultures which were unable to ripen off at all, and at the end of October were still in the thick-necked stage.

Similarly with keeping quality: certain cultures had begun to grow in store before Christmas, others kept soundly (in one case from September, 1926, to April, 1928), while in some cultures there was a mixture of keeping and non-keeping bulbs.

In the case of disease resistance (the disease in question being Neck-Rot or "rotting in store," caused by *Botrytis allii*) results were equally significant. Cultures showed varying degrees of susceptibility to attack; a few appeared immune and some were completely wiped out.

The significance of this information to the vegetable breeder is obvious, and can be applied from the outset to the economic problems which confront him. It is true that to satisfy the scientist and to render explicit the exact mode of inheritance of the various qualities that have been mentioned years of work would be necessary, but for practical purposes the information is immediately applicable.

Future Work—Numerous problems now present themselves with which the early plant breeder was not concerned. When vegetables are mass-produced for the market, there arises the problem of pleasing the eye of the public, since nowadays nearly all buying is done by eye. No matter how solidly a lettuce hearts or how suitable it is for market garden conditions, it is useless sending it to a high-class market if its leaves are tinged with red, or if it is of a pale yellow colour; to the buyer such a lettuce looks stale and old, and he will not give the best price for it. A deep rich-green leaf is required; this looks fresh even when it is stale. Others of the many refinements necessitated by market conditions are: the curd of broccoli and cauliflowers must be white, close textured, and hemispherical; cucumbers must be long, smooth, cylindrical, deep green, and without spines; sprouts for the London market fetch the best price when they are smooth, dark green, solid, and of a prescribed size. There is thus a definite market requirement for each vegetable, and this requirement is usually concerned with appearance rather than with quality.

Similarly, the grower himself is exercised about such questions as time of maturity, hardiness, yield, resistance to diseases and pests, suitability to given conditions of soil and climate, and cultural treatment.

Investigation of these problems—marketing, manuring, diseases, culture—involves plant breeding. One cannot successfully carry out experimental work with material which is not of a uniform character and which, if the seed is obtained through the ordinary channels, may not give the same results from year to year. Thus Jones's "Ideal" Brussels sprout in 1930 may be quite different from Jones's "Ideal" in 1932.

Definite varieties are needed, not stocks which are really collections of varieties in proportions which are constantly varying.

The problems of the vegetable breeder may be briefly stated as follows:

VEGETABLE BREEDING (*Continued*)—

(*a*) Examination and classification of all available material;
(*b*) Selection of types possessing one or more valuable characters;
(*c*) Plant breeding work designed to investigate the mode of inheritance of characters important to the commercial grower; to isolate desirable types; to evolve improved varieties resistant to or immune from certain diseases, suitable to certain conditions of soil and climate, and conforming to market requirements.

This appears a somewhat formidable programme, but it is probable that all the material necessary to carry it out is available in ordinary stocks of vegetables. There are certain obvious limits to the possible achievements of a vegetable breeder; it is, for instance, extremely unlikely that we shall ever see green peas as large as walnuts or onions weighing a stone each. But there is no doubt that, by judicious manipulation of the material at hand, great improvements are possible in the case of many of our cultivated vegetables. D. B.

VEGETABLE GROWING—See Market Gardening; Vegetable Breeding.

VEGETABLE MARROW—See Market Gardening.

VEGETABLES—For methods of preservation by refrigeration see Refrigeration; Preservation, Fruit and Vegetables.

VETCHES OR TARES—Vetches, tares, or "dills" (*Vicia* spp.) are grown in all parts of Great Britain and Ireland for forage and ensilage. They belong to the Leguminosæ, and like all members of that order, are able to fix and utilize the free nitrogen of the air by the aid of symbiotic organisms found in nodules on the roots.

The cultivated vetch is a somewhat fine, square-stemmed plant, varying in height from 2 to 6 feet. Owing to its weak stem it is unable to support itself in an erect position, but clings by means of tendrils formed by an extension of the leaf stems, to any support available. The flowers are papilionaceous and the fruit is a legume, varying in length, size, and in the number of seeds it contains; the seeds also vary greatly in size, shape, and colour.

Botanical—Although vetches are of Asiatic and possibly North African origin, they are widely spread in temperate climates, and exhibit wide differentiation in morphological characters, size and shape of the fruit, and in the number, size, shape, and colour of the seeds. Further, although a few species are perennials, the majority are annual plants.

Three species only are met with in cultivation or wild in the British Isles:—

Vicia sativa L.—the common vetch.
Vicia Cracca L.—the tufted vetch.
Vicia villosa Roth.—the hairy vetch.

Of these, the tufted vetch (*Vicia Cracca*) is perennial, whilst the other two are annuals or occasionally biennials.

Vicia sativa, the common vetch, is characterized by long, trailing,

VETCHES OR TARES (*Continued*)—

square stems; the leaves are compound with four to eight pairs of leaflets and a terminal tendril; the flowers, which are reddish-purple, are axillary, and occur singly or in pairs on short pedicels. There are winter and spring forms of this vetch.

A form of economic importance is the Goar vetch (or summer vetch, Lisle, "Observations in Husbandry," 1757), a larger plant than the common vetch and with larger seeds; this form reaches the stage at which it may be cut, earlier than the common vetch.

Vicia Cracca, the tufted vetch, has a perennial rootstock, and is further distinguished from the two other species by its one-sided racemose inflorescence of purplish-blue flowers.

Vicia villosa, or hairy vetch, is characterized by a long, fine, hairy stem and leaves with long, loose one-sided racemose inflorescence with violet-blue flowers.

This vetch is commonly reputed to possess a high degree of winter hardiness, but the winters in the British Isles are not usually sufficiently severe to permit the display of particular value in this respect. Apart from this feature the plant is very fine and does not appear to produce the same amount of green material (on which the value of the crop rests largely) as the various forms of *V. sativa*, which are, moreover, sufficiently winter-hardy in most seasons.

V. S. Muratova in "Materials to the Determination of the most important Forage Vetches," *Bull. of App. Botany and Plant Breeding*, Leningrad, vol. xvi., 1926, describes twelve species of vetches of agricultural value, and supplies a key for the determination of cultivated vetches.

In the same *Bulletin* A. I. Tupikora publishes an important paper entitled "Botanico-Agronomical Investigations of Annual Vetches."

Suitable Soils—Vetches thrive upon a very wide variety of soils, but a sufficient supply of lime is essential to successful growth. Very heavy crops may be grown on the stiffest clays if well drained, and sandy soils will produce very fair crops if there is an adequate supply of moisture. At Tunstall Light Land Experimental Station in Suffolk the writer found that on a very light soil with a lime requirement of 27 cwts. per acre the crop of vetches was increased at least threefold by an application of 5 tons of chalk per acre (costing, in this case, 50s. per acre including application) four years previously. It is the capacity of vetches to thrive on poor soil which renders them such a desirable crop, and there can be no doubt that to the occupier of poor land vetches are a most valuable aid in increasing the stock-carrying capacity of his farm.

In productivity, vetches rank very high amongst the forage crops grown in this country. Poor land drilled with vetches will produce several times the dry matter, and consequently the stock food, that it will under grass.

The limitation to the utility of the crop, and probably the reason for the relatively small area under cultivation, is the considerable

VETCHES OR TARES (*Continued*)—

amount of labour involved in cutting; this, however, does not apply when the crop is folded with sheep.

Position in Rotation—Vetches do not occupy a very definite position in the crop rotation, but as a rule they are sown after a cereal crop. As they have a considerable smothering effect on weeds of low growth, such as coltsfoot, couch grass, and water grass, they may to some extent be utilized on less clean land. After their removal the land may be ploughed and cleaned, given favourable weather. This is especially the case when the crop is folded fairly early in the summer. If vetches are removed from the land before the first week of July, many seed weeds are also removed, which by that time have not ripened their seed. Vetches are not infrequently followed by an autumn-sown cereal, but on clean, easy-working land, when they are grown as a forage crop and removed or folded in June or early July, they may be followed by a catch crop of turnips. As a rule it is inadvisable to grow vetches on the same land too frequently.

Manuring—Owing to their capacity to thrive upon poor soils, vetches are often left unmanured. Where they are grown for seed on soils of average fertility it may be better not to manure, as there is a danger of producing too much haulm. When grown as a forage crop on rather poor soil, a heavier and often an earlier crop will result from an application of farmyard manure; nevertheless, this manure may often be applied with better returns elsewhere. On heavy soil an application of phosphates—say 6 cwts. of basic slag or 4 cwts. of superphosphate—is a suitable manuring, when farmyard manure is not available. On lighter soils 2 to 3 cwts. of superphosphate and 1 cwt. of muriate of potash or 4 cwts. of kainit will be found suitable.

As noted previously a sufficient supply of lime in the soil is imperative, and where there is a deficiency it should be rectified by the application of this substance in some form.

Sowing—Winter tares are sown in autumn, from September onwards; as a rule, early sowing is best, but frequently there is difficulty in getting seed much before the end of September, as the previous year's crop is often not harvested until early in that month.

Spring tares may be sown at any time from February onwards, and where the crop is intended for soiling or folding successive sowings may be made, and in this way it is possible to secure green tares over an extended period during summer.

The land for tares is usually ploughed, harrowed down, and the seed drilled, but good results may be obtained by broadcasting the seed on the plough seam and then harrowing. Occasionally tares are cut into the stubbles after harvest, without ploughing. In this case the stubbles are worked across with a heavy harrow until a surface tilth is made, and the seed put in with a disc or cup drill, the land being harrowed afterwards to cover the seed. By some this is considered the best way of sowing when the crop is intended for seed. It is, however, open to the objection that the weeds on the stubbles

VETCHES OR TARES (*Continued*)—

are not buried by ploughing, but the plan may very well be adopted when it is desired to "fill up" a faulty plant of clover or mixed "seeds." The quantity of seed tares used per acre varies; 2½ bushels is usual, but as little as 1½ bushels has been known to give good results when the seed has all been well covered.

Vetches grown for soiling, folding, or for silage are usually mixed with oats, rye, or beans, which support the crop and prevent so much of it rotting on the ground. For mixing with winter tares, for soiling, for hay or for folding, winter oats are the best plant to use; rye becomes too fibrous. A mixture of 1½ bushels of tares with 1½ bushels of oats, per acre, makes a useful combination. Spring oats may be mixed with spring tares in the same proportion, but rather more seed per acre is desirable. Provided tares are well covered with soil, and are not subject to depredations by birds, it is undesirable to bury them too deeply; about an inch is the ideal depth.

If it is intended to cut the crop, the land should be rolled in spring, to break down clods and press in stones, thereby preparing the surface of the ground for the mower. It is unusual to horse- or hand-hoe the crop, but docks should be removed.

Vetches for Folding—In an early district, and on early land, vetches may be fit for folding by the middle of May; it is found that sheep do better on them in the early stages than later when the crop becomes more fibrous. They make an excellent fold for sheep, and are grown for this purpose by many of the best sheep breeders.

Soiling—Vetches are most useful for soiling, or mowing green. A small area is grown for the horses on a large number of farms in this country; they are also especially useful for mowing green for milch cows. Farmers who adopt the plan of having a piece of vetches and other green forage crops, such as lucerne and maize, available during most of the summer, as a fodder reserve in case of drought, find that they are able to maintain their milk supply in a dry time, despite the shortage of grass. In most parts of the country winter and spring vetches sown in succession may be relied upon to give valuable green foliage from the last week in May to the end of July or even later. If there is plenty of grass in any particular season, the vetches can be mown for hay or silage, folded with sheep, or allowed to ripen their seed.

Vetch Hay—Vetches, either alone or in mixture with oats, are quite commonly made into hay, but they require a long period of good weather, as the succulent stems are difficult to dry, and in the event of rain when they are nearly in a condition to cart, the hay is seriously damaged. Consequently, on the whole, making vetch-hay must be regarded as rather a risky undertaking. If the crop can be cut before the vetches become prostrate on to the ground, the actual cutting is easier, and then there is less damaged, rotten material. Very often the crop stands up from the ground until mid-June, when a storm of wind and rain beats it down. The quality of the hay is also better if it is cut early, when still in flower, rather than later when flowering has ceased and the pods are approaching maturity.

VETCHES OR TARES (*Continued*)—

A good crop of vetches will produce a large weight of hay, 3 tons per acre being common. Owing to the difficulty of making it satisfactorily, however, probably the best way of preserving green vetches is in the form of silage. (See Ensilage.)

Vetches as a Seed Crop—When vetches are intended for seed, they are usually grown alone. Sometimes a mixture of, say, oats and vetches which it was originally intended to fold or use for forage purposes is allowed to ripen its seed; in this case the two grains may be separated with suitable riddles. Very often, however, the mixture may be sold for seed, as there is a good demand for such mixtures. Occasionally, a few vetches are mixed with beans to secure a good sample of vetch seed; for which purpose 1 peck to 1 bushel of tares mixed with 2 bushels of beans is suitable. Provided only a small proportion of vetches is included, the crop will usually stand up well, and can then be cut with the binder. This plan will frequently result in a supply of good tare seed without the expense of dealing with a crop of tares alone. When a seed crop is grown alone, it is usually cut with the scythe or with pea-hooks, as in the case of peas, but a grass mower with pea-lifters attached to the machine may also be used.

After cutting, the crop must be turned at frequent intervals until ready to cart; turning must be performed even in wet weather, otherwise the pods near the ground will open and shed their seed.

The vetches should be placed in a narrow stack with a ventilating shaft, unless they are harvested in really good condition, and the stack should be covered adequately immediately it is erected. A yield of 32 bushels of seed tares per acre is good, and much smaller crops are common.

The price of vetch seed is subject to wide fluctuations from year to year. If, as sometimes happens, vetch seed is almost unsaleable, it may be ground up and fed to cattle and horses, in place of peas, in the proportion of not more than one part of tares to eight parts of other concentrated food.

Summary—Vetches will produce a heavy weight of green material in practically every part of the British Isles, and are thus a most useful forage crop. They will grow on almost any soil, provided it is not water-logged, or extremely poor in lime. They require very simple cultivation, and owing to their power of assimilating the free nitrogen of the air, will thrive on comparatively poor soil, which they enrich with nitrogen. Hence, they may be regarded legitimately as a most useful crop, suitable alike for the sheep farmer, the milk producer, or the arable farmer, who requires green food for his working horses in summer.

A. W. O.

VIRUS DISEASES—**The Properties of Virus**—For practical purposes we may define a virus disease as an infectious disease caused by something which cannot be seen under the highest powers of the ordinary microscope. What that "something" is, is still uncertain. Some investigators believe it to be a soluble substance akin to a ferment or

VIRUS DISEASES (*Continued*)—

enzyme, others believe it to be a living organism or parasite, perhaps resembling a bacterium or a protozoon, but of very small size; but we require further knowledge before a definite conclusion is possible, and the real nature of virus is at present unknown. Some information, however, is available as to certain properties of virus, and as this may prove to have considerable practical applications, besides the light it throws on the nature of virus in general, it is desirable to give a brief account of these properties as they occur in plants so far as they are yet known. They have been studied mainly in juices extracted from diseased plants, and hold good only of those diseases which can be transmitted by inoculation with such juice. These include many of the common Virus Diseases, *e.g.*, the mosaics of tomato, potato, or tobacco, but in many other equally common diseases, *e.g.*, Leaf Roll of potato, Curly Top of sugar-beet, transmission by juice is either impossible, or succeeds only quite exceptionally. In this latter group the diseases can be transmitted by grafting a part of the diseased plant on a healthy plant, and most of them can also be transmitted by means of insects, so that there is no doubt they are infectious and due to virus, but their viruses do not lend themselves to examination in the same way as the viruses of the first group. What follows, then, is applicable strictly only to juice-transmissible diseases, though there is no reason to doubt that it would be true also for diseases of the second group, if they could be investigated in the same way. (See Tomato, under Glasshouse Crops; Potato, Virus Diseases of; Sugar-Beet, Virus Diseases of; Raspberry, under Soft Fruits.)

The virus of tobacco Mosaic is the one which has been most fully studied, and it may be taken as a typical example with which certain other viruses, *e.g.*, the Mosaic of tomato, agree in all the respects in which they have been examined. Tobacco Virus is readily filterable through tubes of unglazed porcelain, so fine in the pores as to prevent the passage of bacteria; it will even pass through very fine membranes made of collodion. For this reason such viruses are often referred to as "filterable"; but there is a limit to this filterability. When the membrane is made fine enough the virus will no longer pass through, and different viruses vary in their filterability. The extracted juice remains infective for at least five years on simple storage, and probably much longer. When the juice is dried, whether in air or over sulphuric acid, it remains infective, and dried tobacco leaf has been found still to contain active virus after thirty-one years. The virus is not destroyed by heat up to 80° C.; even after two days this temperature may fail to destroy it completely; but it is usually inactivated in ten minutes between 85° and 90° C. This high resistance to the action of heat is of importance, since the ordinary processes of curing the leaf may fail to destroy the virus. It is very resistant to sunlight, and withstands X rays for half an hour, but is destroyed in one hour by rays from a mercury-vapour lamp. When it is well purified, *i.e.*, when it is separated from most of the constituents of the plant juice, it is much more sensitive, and may be inactivated in fifteen seconds when exposed to the open arc. In the tissues of the plant it escapes destruc-

VIRUS DISEASES (*Continued*)—

tion, and no amount of sunshine will inactivate it inside a leaf. When the extracted juice is submitted to pressure the virus can be destroyed, but only with enormous pressures; *e.g.*, 75,000 lbs. for seven days did not wholly destroy it, although 130,000 lbs. for one day inactivated it. It resists acetone, and one hour of 90 per cent. alcohol, and can be brought down in the precipitate by saturation with ammonium sulphate. It is not destroyed by glycerine, toluene, or chloroform, and is resistant to most antiseptics. The juice can be diluted to 1 part in 10,000 (sometimes even further), and still remain active.

It is clear, then, that the virus of Tobacco Mosaic is remarkably resistant, and, as we have seen, there are other viruses which also possess this high resistance. But there are yet other viruses which are much more easily inactivated. Potato Mosaic is filterable through fine filters, but it is destroyed in ten minutes at 80° C., and by 90 per cent. alcohol in an hour, and some strains are still less stable. Rugose Mosaic (the American name for a potato disease very like the British crinkle) is inactivated in ten minutes at 65° C., and in forty-eight hours by simple storage, and other potato diseases of the Mosaic type are even less stable (Johnson, *Res., Bull. 87, Wisconsin Agr. Exp. Stat.*, 1929). Cucumber Mosaic loses its activity in a week on standing, and does not withstand drying, precipitation by even 45 per cent. alcohol, heating over 70° C., or any antiseptic tried except toluene and 5 per cent. chloroform.

There are, then, very considerable differences in the stability of the viruses met with in different diseases. It must be remembered that, as already explained, these tests are commonly carried out with the viruses contained in the juices of the plants from which they are derived, and there is always the possibility that the nature of the juice itself may have a considerable influence on the reactions of the virus to the tests applied. Further, in many cases there is not yet sufficient experience available to guarantee that the results obtained are constant. In the potato diseases, for example, there are, as we shall see, grounds for suspecting that the respective viruses are liable to undergo alterations in their disease-producing powers, and it is not unlikely that the physical properties also will undergo parallel modifications. Much more work must be done before we can arrive at a clear statement and understanding of the phenomena involved, but that there are marked differences between one virus and another is already established.

Classification of Virus Diseases—Ordinarily we recognize a disease by the symptoms it produces, *e.g.*, we say it is a Wilt or a Soft Rot, or a Blight and so on. In many cases, of course, we can go further than these general terms, and from inspection alone can say with considerable confidence that it is such and such a Wilt or Rot, due to such and such a parasite, but in many other cases we cannot make the diagnosis with real certainty, and almost always the final decision depends upon an examination and recognition of the actual parasite. In virus diseases, however, this method of final decision is not at present possible. The virus cannot be isolated and grown apart from

VIRUS DISEASES (*Continued*)—

a plant in which it has developed, and it cannot be seen and recognized by microscopic investigation. The differentiation of one virus disease from another, therefore, depends in ordinary practice (as distinct from experimental work) upon the recognition of the different symptoms they produce. In a number of cases this is reasonably reliable. Leaf Roll of potato, for example, is easily distinguished from Mosaic of potato, Curly Top of sugar-beet from Mosaic of sugar-beet, even simple Mosaic of potato can be distinguished from the ordinary Mosaic of tomato without much difficulty or trouble; and we can be reasonably certain in such cases that, if we could isolate the viruses and examine them in detail, we should find that they do in fact differ appreciably from one another. But in a large number of other cases differentiation by symptoms alone is quite uncertain or even definitely misleading. We may find, *e.g.*, that this potato is suffering from a Mosaic disease, and that other potato has also got a Mosaic, but we cannot say with certainty that the two Mosaics, much alike as they may be, are caused by the same virus. Or, again, we may find one potato suffering from Mosaic and another from Streak, and be unable to say that the two diseases, unlike as they are, must be caused by different viruses; they may be both due to one and the same virus. The symptoms in many virus diseases are quite remarkably inconstant. They vary with the age of the plant at the time of infection, and the period that has elapsed since infection, with its previous treatment (*e.g.*, food supply) or its environmental conditions (*e.g.*, temperature, light), and with a number of other factors, of which some are not yet analysed. In particular, the variety of plant is often of the greatest importance to the symptom expression. It is only to be expected that one virus may produce very different diseases in plants belonging to widely different species (though this is not, as a matter of fact, always so), but within the same species the symptoms produced in different varieties by a single virus may range from the mildest of leaf-mottles (or even, as in "carriers," none at all) to a virulent necrosis rapidly fatal. The great difference which may exist between one variety and another is familiar in other diseases than virus, *e.g.*, in Wart disease where some varieties are immune, others susceptible; and in virus diseases we have a similar wide range of response to a simple disease-producer.

Under these circumstances symptoms alone often give us no more than descriptive labels to attach to different appearances, *e.g.*, Mosaic, Rosette, Crinkle, and yellows; they do not enable us to draw conclusions as to the identity of the particular viruses causing them. This fact is a great hindrance to the accurate investigation of virus diseases, and has been the cause of much confusion. One of the great requirements in Virus work is some method of distinguishing one virus from another. If we kept a series of standard plants grown under standard conditions, which we infected with standard viruses, we might perhaps in time learn to recognize the different types of symptoms each virus produces in each kind of host, and eventually be able to recognize it in the field under varying conditions. To be complete, this would involve long,

VIRUS DISEASES (*Continued*)—

difficult and laborious research, and it has not yet been done; but it may prove to be necessary, and various investigators are working at it. A more rapid method would be to transfer, in any particular case requiring diagnosis, the virus from the case to a series of standard plants, and from the results determine what the virus was. This method assumes that the viruses are comparatively stable, and are unaltered by their passage through other hosts or varieties, and accordingly it works well with such viruses as the Mosaics of tobacco or tomato or with Leaf Roll of potato. These may, it is true, be altered in some characters by abnormal treatment, such as exposure to very high temperatures or excessive oxidation, but normally they remain fairly constant, and when brought back from other hosts to the standard plants give, as a rule, the standard type of symptoms. But there are many viruses of which this is not true. This is particularly so in the very difficult group of the Potato Virus Diseases, but it occurs with other viruses as well: Cucumber Mosaic, for example, ordinarily very constant, undergoes attenuation in some hosts, and when brought back to cucumber no longer gives the same disease. In potato this inconstancy is very striking. For example, take a case recently discussed by Salaman (*Proc. Roy. Soc.*, B. 106, 50), that of Crinkle in the variety President. When grafted to healthy President it reproduces the Crinkle, but grafted to the variety Abundance it produces a Mosaic, and grafted to Epicure or Great Scot it induces violent Streak. Moreover, when brought back from Abundance to President again, it may not reproduce the original Crinkle: it has been altered in some way in the other host. Further, while grafting Crinkle President to President gives Crinkle, transference of the disease by simple inoculation with a needle does not give Crinkle, but a mild Mosaic. Other cases of this sort are known, and it would seem that many viruses are very unstable and easily altered in their disease-producing properties. Differentiation by symptoms alone in such cases is a very uncertain guide to the identity of the viruses producing them.

Under these circumstances there has been a desire to find some method of distinguishing between viruses which are independent of symptomatology; and attempts have been made to make use for this purpose of such properties as those described above. We can, for example, distinguish between the virus of Tomato Mosaic and that of Cucumber Mosaic, even when both are in plants of the same species or variety, by exposing them to 75° C. for ten minutes: the Cucumber Mosaic will be killed, the Tomato virus remain alive. In the case of a mixture of two such viruses, again, we can destroy one and leave the other in the same way. As yet, however, differentiation on such lines has not got very far, and it is still uncertain to what extent such methods will prove of real value in distinguishing between closely related viruses, *i.e.*, in the cases where it is most wanted. In particular there is still doubt as to the constancy of such reactions. In some cases, however, they are undoubtedly of value, and it may be that improved methods will extend the range of their applicability.

J. H. S.

VITAMINS—For significance and requirements in nutrition of farm animals, see Foods and Feeding.

WAGES AND LABOUR—Of persons employed in agriculture in Great Britain, wage earners constitute by far the most numerous class. If we include horticulture and fruit growing, the number employed in England and Wales approaches 800,000, as against 300,000 "farmers," *i.e.*, persons either employing labour or working on their own account. For Scotland the proportion is not substantially different.

The following Table, from "The Agricultural Output of England and Wales, 1925," H.M. Stationery Office, shows the number of workers (excluding the occupiers of holdings) employed in farms of the various size classes, the number being reckoned in each case per thousand acres of crops and grass:

Number of Agricultural Workers in England and Wales per 1,000 Acres of Crops and Grass, according to Size and Type of Holding, in 1924.

All Holdings (excluding Fruit, Vegetable and Poultry Holdings).	*Regular Workers.*			*Casual Workers.*			*Total Workers*
	Males 21 and over.	*Males under 21.*	*Women and Girls.*	*Males 21 and over.*	*Males under 21.*	*Women and Girls.*	
Acres.							
1 to 5	20·0	6·7	3·4	8·9	2·7	1·6	43·3
5 to 20	14·9	5·4	3·4	5·7	1·9	1·5	32·8
20 to 50	13·7	6·0	3·2	4·8	1·6	1·5	30·8
50 to 100	14·4	5·9	3·1	4·0	1·2	1·3	29·9
110 to 150	15·0	5·3	2·5	3·3	0·9	1·3	28·3
150 to 300	16·1	4·7	1·8	2·6	0·7	1·3	27·2
300 to 500	18·1	4·4	1·3	1·9	0·5	1·2	27·4
Over 500	19·2	4·5	1·0	1·4	0·4	1·0	27·5
Total	16·0	5·1	2·2	3·1	0·9	1·3	28·6
Fruit and vegetable holdings	87·2	24·2	15·1	21·6	8·4	37·2	193·7
Poultry holdings ..	48·4	28·8	9·1	16·0	6·0	4·0	112·3

In the foregoing Table the figures for the smallest class of holdings have little significance. For the rest, it appears that the average number of persons employed per thousand acres is about twenty-eight, or one person to approximately 36 acres. It will be obvious that if we add the occupier in each case, the total labour strength per unit area declines steadily as we progress from the smaller to the larger holdings. On the other hand, it is noteworthy that after a certain point the number of permanent male workers per unit area tends to increase. A classification of all holdings into the groups "mainly arable" and "mainly grass" showed, as might be expected, a substantially higher figure for the former, viz., 36·6 as against 23·1. This same point is illustrated if we compare separate counties, as is done in the following table; but there are, of course, other important causes of variation. Thus, in the Fens the large proportion of the

WAGES AND LABOUR (*Continued*)—

arable under potatoes, sugar-beet, and vegetables makes for a higher labour requirement than the typical corn and stock farming of Norfolk. Again, Cheshire, with its predominant dairy industry, employs relatively more workers than Devon, where dairying is only one industry among many:

	Percentage Arable.	*Number of Workers per 1,000 Acres.*
Lincoln (Holland)	78·0	61·6
Norfolk	75·0	42·1
Bedford	56·4	38·3
Nottingham	50·0	27·0
Devon	41·1	25·9
Cheshire	35·8	39·8
Derby	18·7	23·5
Westmorland	15·5	19·2

Wages—In England and Wales minimum rates of wages are determined under the Agricultural Wages (Regulation) Act, 1924. Rates for each county are fixed by District Committees whose orders have the force of law; the responsibility for enforcing payment rests with the Ministry of Agriculture. Each Committee consists of equal numbers of representatives of the employers and workers, with a neutral Chairman. The average of the minimum wage rates, for the country as a whole, remained fairly constant at about 31s. 6d. per week during the first seven years that the Act was in operation. During that period the cost of living fell by approximately 13 per cent., so that real wages may be said to have been increased by that amount. Stockmen and horsemen receive extra pay on account of their longer hours: the weekly wage for these special classes averaged about 37s. for the period in question. In Scotland there is no machinery corresponding to that above described; in some districts there are standard wages for workers of each class, which are determined by collective bargaining and are reviewed annually. In other areas wages are largely a matter of private bargain between the individual master and man. Until 1930, wages in Scotland were somewhat above those of England, averaging in that year 38s. per week for married and 33s. for single men.

In some districts the calculation of the cash value of the wage is a matter of difficulty on account of the prevalent system of allowances, *i.e.*, the practice of payment partly in goods. Generally speaking, the farther north we go, the greater is the proportion of the wage paid in this form. In Scotland, as a whole, allowances constitute about 20 per cent. of the gross wage. For married workers these take the forms of free houses and gardens, oatmeal, milk, potatoes, and sometimes fuel. The keep of a cow is included in certain areas. For unmarried employees full board is provided in certain cases, while in others "bothy" accommodation with fuel, light, meal, milk and potatoes is supplied. In England and Wales, houses are frequently rent free, or let at nominal rents; otherwise there is no general system of allowances in use, although in particular cases potatoes, bacon, and milk are supplied either as part of the wage or at preferential prices. This

WAGES AND LABOUR (*Continued*)—

system has been frequently criticized as inapplicable to modern conditions, and it is probably tending to disappear with the development of road transport, and of what are practically travelling provision shops. In some cases, *e.g.*, where large allowances of oatmeal are made, the system has the objectionable effect of forcing upon the wage-earner a commodity that he does not want, and which he may find difficult to dispose of at a fair price.

The customary hours of work vary from district to district, but average about fifty hours per week.

Special Systems of Payment—Despite the theoretical advantages of other possible systems, the great bulk of farm labour is still paid on a time basis, *e.g.*, by means of an agreed sum for a standard working week, with agreed rates for overtime. Attempts to improve on this method have taken three chief forms, viz.: (1) piece-work rates; (2) bonus payments; and (3) profit-sharing schemes.

For the satisfactory operation of the piece-work system, the following conditions are necessary: (1) The quantity of work done must be readily measurable; (2) the quality of the work should be easy to check; (3) the quality and quantity of work done should depend primarily on the industry and efficiency of the worker himself.

Examples of operations to which the system is applicable are singling and harvesting roots, hand-spreading farmyard manure cutting and laying drains, thatching, etc. It may be applied to other than hand-tillage operations with the risk of excessive wear and tear on horses and machines. It is not easily applicable to operations where the individual works as a member of a squad, or to operations like drilling or cultivating, where the quality of the work is of prime importance and is not immediately apparent.

The underlying idea of the bonus system is to encourage diligence and efficiency, while at the same time giving the worker a guarantee that his emoluments will not fall, through the accident of circumstances, below a specified sum. As examples of bonuses that have proved easily workable and at the same time have usually had the desired results may be mentioned the following: (1) In graded milk dairies, a bonus to the cowmen based upon the bacterial counts of the milk; (2) in breeding flocks of sheep, a bonus to the shepherd for every lamb reared in excess of a certain basal number; (3) a bonus on output, above a certain specified amount, in operations like sorting potatoes, where several persons work in conjunction. Amongst arrangements that have been tried but have sometimes had undesirable results may be quoted: (1) A bonus to cowmen on the yield of the herd; (2) in pedigree herds a share of the prize money, from shows, etc., paid to the stockman.

Profit-sharing schemes in agriculture suffer under the disadvantage that the industry is subject to cycles of depression during which, even with the most efficient management, losses are sustained for several years in succession. Under such circumstances, the schemes can only survive if the workers have a very high degree of confidence in the management. Moreover, a very careful annual audit and very clear

WAGES AND LABOUR (*Continued*)—

and precise conditions are necessary if disputes and jealousies are to be avoided.

Labour Requirements—The man-power required for a given farm may be arrived at on the basis of the acreage of the various crops grown and the numbers of the several classes of stock maintained. The following tables (from Watson and More's "Agriculture," 2nd edit., Oliver and Boyd, Edinburgh and London) are based on data collected from cost accounts and from farm surveys:

MAN LABOUR (DAYS PER ACRE).

	Maximum.	*Minimum.*	*Average.*
Cereals and beans	9	4·0	7·0
Peas	12	7·0	10·0
Potatoes	40	20·0	33·0
Roots, carted	25	15·0	20·0
Roots, folded	14	10·0	12·0
Sugar-beet	40	20·0	28·0
Carrots	70	50·0	60·0
Rape, vetches, etc., folded	8	4·0	6·0
Hay	3	2·0	2·5
Pasture	1	0·1	0·3
Pasture, intensive system	3	2·0	2·5

MAN LABOUR (DAYS PER HEAD PER ANNUM).

	Maximum.	*Minimum.*	*Average.*
Dairy cows, hand-milked	30·0	20·0	24·0
Other cattle, housed	10·0	6·0	8·0
Other cattle, outside	5·0	3·0	4·0
Pigs, indoor system	2·0	1·2	1·5
Pigs, outdoor system	3·0	2·0	2·5
Sheep, arable	2·0	1·0	1·5
Sheep, semi-arable	1·4	0·7	1·0
Sheep, grassland and mountain	1·0	0·5	0·7
Poultry	0·6	0·3	0·4

From the above it is possible to make an approximate calculation of the number of man-days per annum that will be required for the operation of a farm upon a given system. Obviously, however, the seasonal distribution of the work must receive full consideration unless the staff can be quickly reduced or strengthened as required. This question is further discussed under "Farming Systems."

In the following table (Watson and More, *loc. cit.*) data are given of the approximate amounts of work carried out per day, by average workers under average conditions. The actual figures, of course, require modification in relation to soil and weather for field operations, and in relation to the degree of convenience in feeding arrangements, etc., for live stock.

The organization of the labour force on the farm, and the management of the workers, make one of the most important and most difficult of the farmer's tasks. In order that it may be effectively done the manager must possess an intimate knowledge of all the operations that the workers have to perform, and a personal knowledge, not only of the physical strength and skill, but also of the mental powers and

WAGES AND LABOUR (*Continued*)—

LABOUR.

Operation.	*Width.*	*Per Eight-Hour Day.*
		Acres.
Ploughing lea	8 ins.	⅔
Ploughing stubble	9 ins.	¾
Cross-ploughing	10 ins.	1
Tractor ploughing	2 furrows	2½
Ridging	27 ins.	3
Harrowing	9 ft.	14
Cultivating	7 ft. 6 ins.	10
Grubbing	4 ft. 6 ins.	6
Rolling, 2-horse	9 ft.	12
Rolling, 1-horse	6 ft.	8
Disc harrowing	6 ft. 6 ins.	7
Horse-hoeing, 1-horse	Single drill	3½
Three-row horse-hoeing, 2-horse	6 ft. 9 ins.	9
Drill grubbing, 2-horse	Single drill	3
Potato lifting (full set of 20 lifters)	—	3
Singling roots	9 ins.	⅓
Lifting roots	—	⅓
Hand-hoeing roots	—	½
Cutting with binder	5 ft.	6
Cutting with mower	5 ft.	8
Drilling seed	8 ft.	10
Broadcasting by hand	—	18
Broadcasting by grass seed machine	16½ ft.	18
Swath-turning	2 swaths	16
Stooking 5 qrs. crop of wheat	—	2½
Sowing fertilizers with machine	—	10
Planting potatoes (set of 5 planters and lad carting seed)	—	3½
Sowing turnips	2 rows	8
Cutting with scythe	—	⅘
		Tons.
Carting dung ⅓ mile to heaps in field (3 carts and helper to fill)	—	24
Carting turnips ⅓ mile from field to steading (3 carts and helper to fill)	—	24
		Cwts.
Thrashing wheat and oats	—	240
Thrashing barley	—	280
		Sheep.
Clipping short-wool sheep	—	16
Clipping half-bred	—	30 to 40
Clipping blackface	—	80 to 100
		Cows (per hour).
Milking cows	—	7

character, of every individual employee; otherwise he will be certain, at times, to let pass idleness or slipshod work, or else to impute blame where the worker has done honestly and well. The organization of labour cannot be learned except by experience, and the quickest and

WAGES AND LABOUR (*Continued*)—

best method is to work under a competent farmer, thinking out each day's problem independently and discussing every case where the master's solution differs from the pupil's.

The articles entitled Farm Capital, Farming Systems, and Farming Costs and Accounts should be read in conjunction with this article.

J. A. S. W.

WAGGONS, DRAFT OF—Considerable economies in power and expense in connection with horse traction may often be secured by a careful study of the conditions both as to type of road and that of vehicles employed, as well as, in the case of horses, etc., the type of animal used. Unfortunately, limitations of space prevent any proper discussion of these points here, but the reader will find himself well repaid by the study of F. H. King ("Physics of Agriculture," Madison, Wis., pp. 428-443 and 486-502, 1914), where the whole question is simply yet clearly treated. Shortly, it may be stated that the draw-bar pull required to move any load depends upon the smoothness and rigidity of the road bed, on the tyre width, diameter of the wheels, on the distribution of the load on the carriage and the rigidity of the latter, on the direction of the line of draft, and on the type of bearings and their lubrication. The following rules hold *generally*, but not universally: the smoother and more rigid the road bed, and the greater the diameter of wheel and width of tyre, the less the draft. The larger and wider wheels should bear the heavier load in a waggon where the wheel sizes differ, and the line of draft should rise somewhat from the horizontal. A sprung carriage draws more easily than an unsprung one. The *better* made the road, the *more* objectionable is a steep hill upon it. Remarkable as this seems, it is easily understood, since a good road allows of heavier loading of waggons, and although these loads may be moved on the level with the same draw-bar pull as a lighter load on a poorer quality road, yet when a hill is encountered the *additional* pull required is a fraction of the total weight depending on the gradient, and hence is much greater for heavy loads than for light ones on equal gradients. The principle of eveners and the points of the draft horse will be found clearly treated and connected with physical principles by King (*loc. cit.*), to whose work the reader is referred for a fuller treatment of the whole subject.

WALES, Agriculture of—See Agriculture.

WALNUT—See Nuts.

WARPING—Warping (to warp = to scatter, sprinkle something on a surface: Murray's "New English Dictionary") is carried out with the object of securing the solid material suspended in the waters of tidal rivers or estuaries. This is done by allowing the water of the rising tide to flow over land in the vicinity of the river, and also to leave the land as easily when the tide ebbs. To accomplish this it is evident, therefore, that the land to be warped must be at a lower level during the incoming tide, and especially during high tides, than the water in the river.

WARPING (*Continued*)—

The practice is carried out in England only on land, of very considerable extent, adjoining the estuary of the Humber and its tributaries the Trent and Ouse—land which is protected against the daily tides by banks high enough to prevent the waters of these and also of the highest (spring) tides from inundating the country. By whom these banks were made is not now known, but they are of great size and strength, and preserved very valuable flat land that otherwise would have been swamps.

The incoming tidal water of the Humber contains a large amount of mineral matter or mud in suspension which, when recovered by the system, provides a soil rich in itself and potentially capable of growing large and remunerative crops. The method has been practised for many years, and valuable accounts are to be found in the *Journals* of the Royal Agricultural Society—viz., vol. v. (1844), vol. xi. (1850), vol. lxxiii. (1912); in vol. xliii. of the Society for the Encouragement of Art; and in a paper by Mr. W. D. D. Jardine, formerly District Lecturer in Agriculture, the University, Leeds, to Section " M," British Association, Leeds Meeting, 1927.

The system, whilst fundamentally simple in conception but brilliant in result, to be carried out effectively requires some engineering skill. A large open ditch, known as the warping drain, is cut from the bank on the shore of the river or estuary, and can be extended inland as far as the tide will reach.

The bed of this drain has a uniform fall towards the river. Furthermore, it also follows that the surface of the land in the neighbourhood must be higher than the bottom of the drain, so that all the water from the first tide admitted on to the land may flow off during the ebb, leaving behind a thin muddy deposit which becomes partly dried before the next tide is allowed to enter to contribute its quota of mud. The warping drain must be of sufficient dimensions to allow a large body of tidal water to reach the area to be warped as quickly as the tide rises. An idea can best be formed of the size of such a drain from the dimensions of one made by Mr. Creyke in 1821, which extended for three miles—viz., " 30 ft. wide at the bottom, 90 ft. wide at the surface of the land, and 11½ ft. deep; the banks were placed 9 ft. from the edge of the main drain, the base of each bank was 60 ft. wide, and they were 10 ft. high." The cost of making this drain " with the purchase of the land and the erection of the sluice was £18,000."

" The sluice or cough was built of stone with two openings of 16 ft. each in width, and 19 ft. in height from the sole to the crown of the arch, with four substantial doors, made when shut to oppose the entrance of the tide, yet with power at will to keep them open for the admission of the tide during the time of warping, by means of strong staples and iron rods fixed in the stonework." Mr. Creyke states that " from observation and calculation the area of a warping drain ought to be three times that of the sluice to prevent as much as possible any considerable resistance to the flow of the water." (See Fig. 32.)

Both banks must be so high that the waters of the spring tides are retained within the drain and cannot overflow on to the surrounding

WARPING (*Continued*)—

land. The mouth of the drain at the river is guarded by a sluice gate or gates which can be opened or closed at will, so that the admission of the tidal water into the drain is completely under control. The warping drain may be regarded as a permanent water channel for the ingress and egress of the tides whenever an area of land is to be treated.

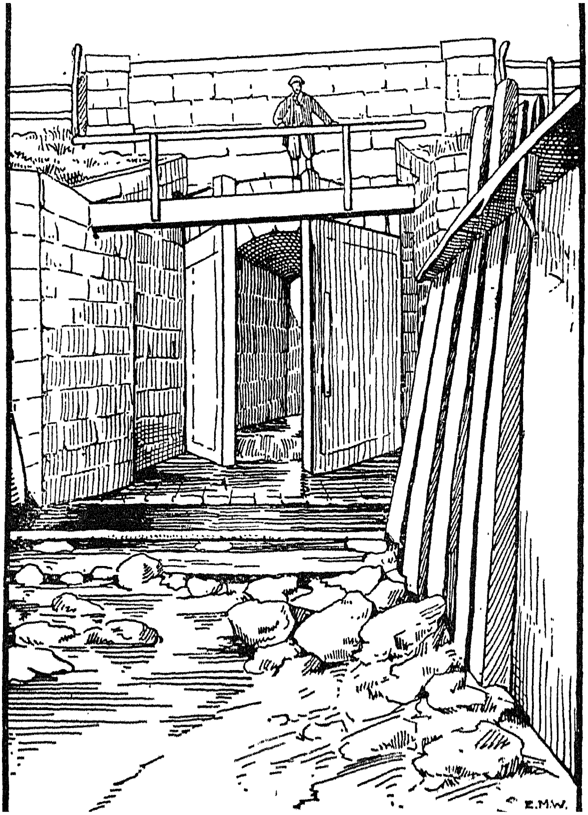
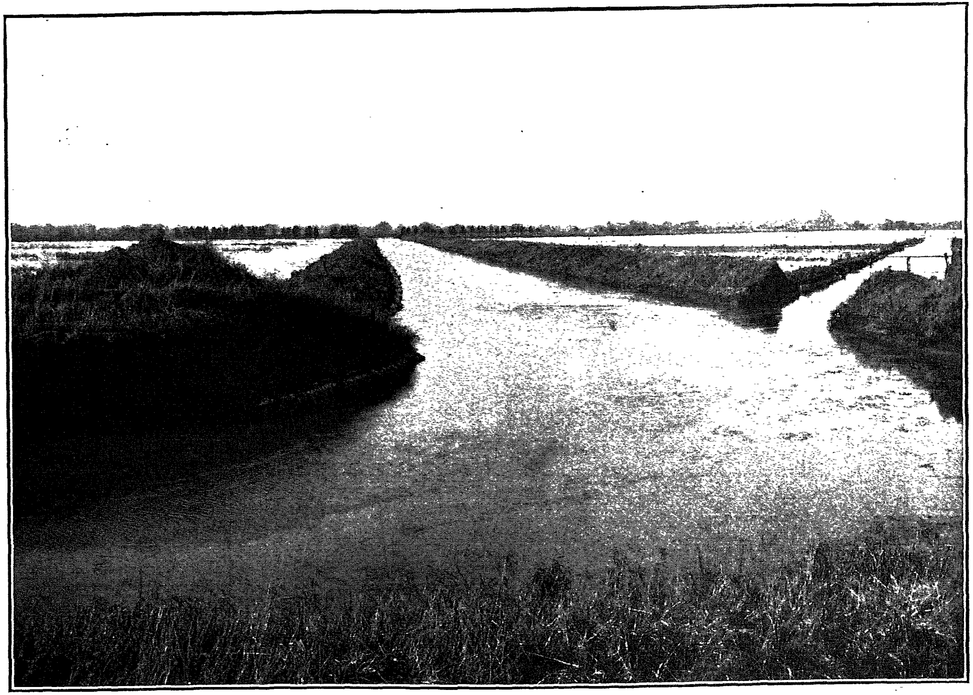


FIG. 32.—SLUICE GATES AT ENTRANCE TO WARPING DRAIN AT BLACKTOFT.
Height, sill to arch, 13 ft. 6 ins.; width, wall to wall, 13 ft.

The area to be warped having been decided upon, it is entirely surrounded by banks as high as the highest spring tides, and of sufficient width at base and top to withstand the weight of water inside the "compartment," which may be as much as 160 acres in extent.

The bank of the warping drain is cut at a point from which proceeds a main ditch, which is made approximately through the middle of the area to be warped, and to its farthest point. The warping drain is blocked at this point, so that no tidal water can go further inland, but all be diverted into the confined area. The tidal water then

PLATE XXIII



INLETS TO ENSURE EVEN DISTRIBUTION OF THE WARP WATER ENTERING AT HIGH TIDE FROM MAIN WARPING DRAIN IN IMMEDIATE FOREGROUND.

Estate of Major Empron, Yokefleet, Yorks, July, 1928.

To face p. 1250

WARPING (*Continued*)—

gradually comes up the warping drain, and can only find its way into the central ditch. The water flows to the farther side of the "compartment," and is diverted either left or right into the ditch, which has been made by the soil thrown out to form the bank right round the compartment. (See Plate XXIII.)

Whilst the banks of the main ditch or "run" are being made, inlets are also fixed with doors which can be opened or closed as desired. Subsidiary shallow ditches are made to direct the flow of water over the land. The main ditch or "run" is directed towards the lowest part of the field, as it is essential that that portion should be warped first, so as to bring it to the level of the other portions of the compartment, after which there will be no difficulty in the water flowing completely off when the tide ebbs. Failure to attend to this will result in the lower portion becoming a pond by the gradual heightening of the general surface of the high land by the accretion from each tide. The banks and runs, a rather expensive piece of work, are made during the winter, and warping is not commenced until after the heavy spring tides have passed. Ordinary tides are admitted first, and only intermittently until the banks have become soaked and settled sufficiently to withstand the heavy weight of water of the first spring tides that are admitted. Before the first tide is admitted all the outlets of any existing pipe drains are blocked as well as any passing through the banks, so that they may stand full of water and are thus prevented from being silted up.

The material in suspension consists of particles of varying size from coarse sand to the finest clay. As the heavier particles will settle out first, it is important that the runs, etc., are so arranged as to permit the water reaching the furthest and the lowest sides of the compartment as speedily as possible with the object stated above, and also to obviate the risk of the heaviest particles becoming deposited in too close proximity to the warping drain, and thus defeating the object of getting the whole field uniformly warped. Spring tides, during dry weather, contain the greatest amount of suspended matter. Periods of heavy rain reduce the value of the incoming tide—there is too much "fresh" as it is called. Frosty weather is said to interfere with deposition, as also does windy weather, which keeps the extensive sheet of water turbulent. It is incumbent, therefore, that a man with experience of the tides and acquainted with all the details of warping should be responsible for deciding as to the opening or closing of the sluice gates during the period of warping, which may extend to eighteen months or more, and include two summers.

Every tide is not allowed to cover the land, and so there is time for the deposit to dry a little between tides, which is regarded as contributing to the excellence of the final warp. Weak banks from too little material having been thrown up may also mean too low banks, in which case the highest spring tides carrying the greatest amount of sediment cannot be admitted. Most material is brought in suspension with the spring tides during a dry summer. It is false economy, therefore, not to spend enough money on banks and runs.

WARPING (*Continued*)—

The total cost of warping may be about £18 per acre, which includes all labour expenses and three years' loss of rent.

The amount of new soil deposited during a season varies, but it is on record (*J.R.A.S.E.*, p. 403, 1844) that in one compartment of 160 acres a deposit of from 1 to 3 ft. was obtained in seven months. Warping was begun in June, 1829, and finished in January, 1830, but this may be regarded as an exceptional case.

The following mechanical analyses (Agricultural Education Assoc., 1906, "Method of Analysis"), kindly supplied by Mr. Trefor Jones, M.Sc., Lecturer in Agricultural Chemistry and Advisory Chemist, the University of Leeds, illustrate the varied character of the soils produced:

	Virgin Warp, Goole.		*New Warp, Gilberdyke.*		*Old Warp, Brough.*	
		No. 4.	*No. 6.*	*No. 8.*	*Old Grass.*	*New Grass.*
	%	%	%	%	%	%
Fine gravel ..	—	—	—	—	0·04	0·06
Coarse sand.	0·30	0·23	7·10	0·04	0·54	0·27
Fine sand	59·00	43·96	22·17	1·17	12·53	8·01
Silt ..	11·34	17·70	11·03	11·20	26·60	18·79
Fine silt (*a*)	2·28	4·89	10·80	12·75	9·98	13·75
Fine silt (*b*)	2·80	6·00	10·53	11·35	7·89	10·74
Clay ..	1·65	7·60	17·03	33·63	16·16	23·80
Moisture	1·36	1·73	3·16	4·09	3·69	4·54
Loss on ignition	8·96	9·53	10·37	15·29	14·56	6·61
Loss on solution	12·41	11·98	6·95	17·46	8·82	10·60
	100·10	103·62	99·14	106·98	100·81	97·17

When it is considered that sufficient warp has been deposited, and after the last tide has ebbed, the pipe drains are opened so that the land may dry quickly. Warping generally is expected to be finished in August or early September, and as soon as the land is sufficiently dry Italian rye-grass (9 to 10 lbs. per acre) is broadcast by the "fiddle." Harrowing is not possible, and the seed has to germinate in the cracks or on the surface. One, or even three, crops of rye-grass hay are taken in the following season, and in some cases the third crop is ploughed in for the benefit of the next crop, generally potatoes. The first crop may yield 2 tons of hay and the second 1½ tons per acre. (See Plate XXIV.)

Potatoes may be grown in the two following years with yields of about 10 tons per acre each year, and without any manure. Mustard is then (fourth year) grown for seed, and yields about 24 bushels per acre. Wheat (about 5 quarters per acre) follows mustard, and in the sixth year oats, with a seeding of clover. For the latter crop, farmyard manure, about 10 tons per acre, with some artificial manure, is applied. Thereafter, a typical warp rotation may be taken as: first, potatoes; second, mustard; third, wheat or oats; fourth, "seeds."

The writer is indebted to Dr. A. G. Ruston, Lecturer on Agricultural Economics, the University, Leeds, for the accompanying photographs, and to Miss E. M. Wright for the drawing of the sluice gates at Blacktoft.

R. S. S.

PLATE XXIV

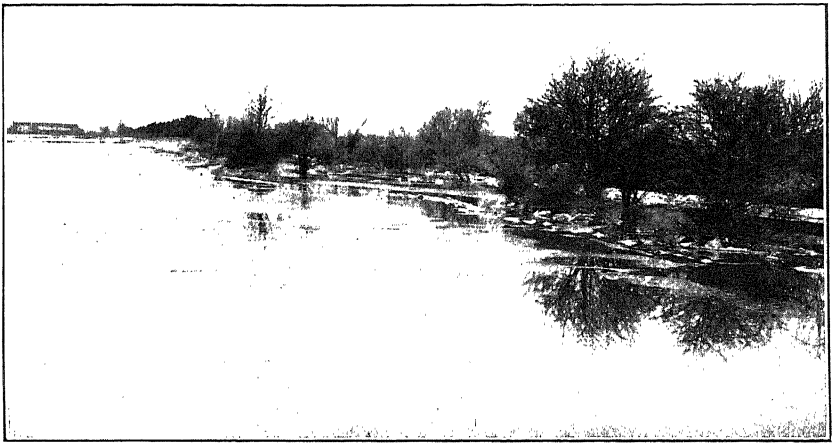


FIG. I.—WATER DRAINING OFF AFTER LAST TIME ADMITTED. NOW LEFT FOR CONSOLIDATION BEFORE SOWING.

Metham, Yorks, June, 1929.

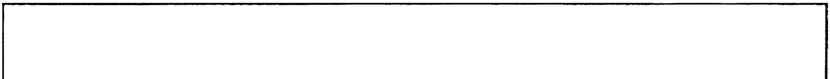


FIG. 2.—USING CLEAT BOARDS FOR BROADCASTING RYE-GRASS WITH FIDDLE DRILL ON NEW WARP.

Estate of A. J. S. Shaw, Esq., Metham Hall, Yorks, 1929.

WATER AND WATER SUPPLIES—Chemically, water is hydrogen monoxide (H_2O). Although found naturally in great abundance over the surface of the globe and in the air, it never occurs in a state of chemical purity, but always contains more or less of dissolved substances of varying nature. Although these do not normally exceed $\frac{1}{10}$ of 1 per cent., it is to them that attention must be directed when the question is one of the potability of the water or of its suitability for stock, for washing purposes, or for use in boilers.

The naturally occurring waters may be divided into four classes—rain water, surface water, subterranean water, and sea water. The first is very pure and suitable for most purposes, but is limited as to the amount which can ordinarily be collected, and is almost entirely deficient in those minerals, chiefly lime, which are so necessary to the proper development of growing animals. Surface water is of very variable composition, the purest being that collected in lakes in mountain regions, many of which have been connected to large towns by long aqueducts for their water supplies, *e.g.*, Loch Katrine (Glasgow), Thirlmere (Manchester), Lake Vyrnwy (Liverpool).

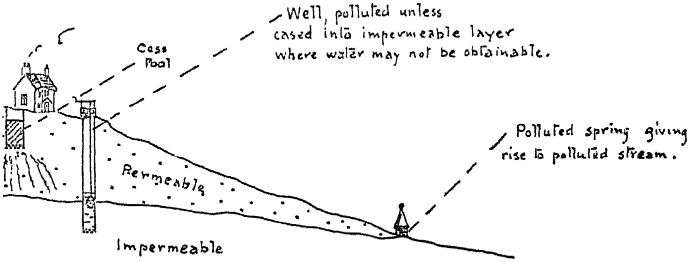

Well, polluted unless cased into impermeable layer where water may not be obtainable.
Cess Pool
Polluted spring giving rise to polluted stream.
Permeable
Impermeable

FIG. 33.—SEWAGE CONTAMINATION OF WELL AND SPRING.

Ponds or lakes of small extent are often less desirable sources of water for drinking, as a small amount of pollution has a greater proportionate effect. The water in them is frequently almost stagnant for two reasons: firstly, the water of the feeding stream often passes across them without having much chance of mixing with the pond water; and, secondly, their surface is but little disturbed by storms which raise waves of considerable magnitude on the surface of the larger lakes, causing appreciable mixing and aeration. Water from rivers and streams is very commonly used for drinking, and flowing water gradually purifies itself by continuous oxidation, but a blind trust in the purity of running water without any consideration of the possible sources of pollution to which it may have been exposed has been responsible for many outbreaks of typhoid fever.

Subterranean water, if arising from a great depth, especially where an impermeable stratum has first to be traversed, is usually good for drinking, though its mineral constituents may be unusual, and even possess purgative properties. That from near the surface, however, be it well water or spring water, is almost as liable to pollution as surface water. Fig. 33 shows how sewage contamination of such water

WATER AND WATER SUPPLIES (*Continued*)—

may occur even at a considerable distance. Sea water, of course, does not concern the farmer directly.

The impurities which are of importance in a water will, of course, depend upon what it is to be used for—slight sewage pollution does not matter when it is to be employed in boilers, or even normally for stock, whereas it must be guarded against for drinking purposes. The pure waters of mountain lakes are excellent for drinking by adults, but not so good as many less pure limestone waters for young stock, as, unless the requisite lime is otherwise provided, they tend to induce rickets.* Water highly charged with lime salts, *i.e.*, very hard water, is unsuitable for washing or for boilers, causing waste of soap and time, and furring up the boilers to a marked degree.

"Hardness" in waters may be of two kinds: (*a*) temporary, (*b*) permanent. A water is said to be temporarily hard if the hardness can be removed by boiling. Such hardness is due to the water holding in solution a certain amount of calcium bicarbonate formed by the solution of chalk or limestone in water previously charged with carbon dioxide. This solution is decomposed on boiling with re-precipitation of the calcium carbonate, leaving the water soft. If the dissolved matter in the water consists of calcium sulphate from its having been in contact with gypsum, for example, the hardness cannot be abolished by boiling, and the water is said to be permanently hard. On Clark's scale of hardness this quality is estimated in degrees, each corresponding to 1 grain of calcium carbonate in a gallon of 70,000 grains, substances other than calcium carbonate being converted into terms of this by the usual chemical factors. Waters of up to 5 degrees of hardness on Clark's scale are regarded as soft, while those of more than 15 degrees are regarded as hard. Although the only exact method of determination is a careful chemical estimation of lime and magnesia present, it is usual to be satisfied with a rougher estimate depending on the formation of a lather with soap, proposed by Clark and called after him. For this test a definite volume of the water is taken, and a standard solution of pure Castile soap is dropped in from a burette until a point is found after which the addition of another drop of the soap solution enables a lather to be produced on the surface of the water by shaking. Reference from the results of this test to the standard scale of hardness is made by means of a prepared water of known hardness.

The geology of a district has a considerable influence on the type of water and on the quantity that may be expected to be encountered in any well sinking or boring operation. The subject is too wide to be treated within the scope of this article. Any reader who is interested may consult H. B. Woodward, "The Geology of Water Supply," Arnold, London, 1910, pp. 17-35 and 143-224, where the matter is dealt with in some detail. Shortly, it may be stated that permeable materials such as sand, gravel, soft sandstone, sandy limestones,

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* Children usually escape this, as the farinaceous food eaten normally supplies all the lime necessary, and the same presumably applies to other young animals to which cereals are fed in any quantity.

WATER AND WATER SUPPLIES (*Continued*)—

chalk, oolite, dolomite, and brown ironstone commonly yield water easily, while clay, shale, tabular flint, slate, schists, granite, greenstone, hard limestone, marble and conglomerates do not. This statement must, nevertheless, be modified in several regards—practically all the rocks in the latter list frequently occur in a more or less shattered condition, and may, and often do, hold large amounts of water in joints, fissures, caverns, faults, etc., and when a well makes no natural connection with these, a blast charge fired at the bottom will often effect this. Furthermore, some very fine sands or silts and sandy loams, although containing considerable quantities of water, are very shy of yielding it up.

In time past it has been customary to tap these underground supplies by means of dug wells; in later years, however, the advantages of the bored type* common in America have been more and more recognized. They can be sunk to a much greater depth in a much shorter time, and are consequently cheaper to construct; moreover, there is no great difficulty in traversing layers of impermeable rock to tap water-bearing strata below. The types of borers and drill bits used in sinking such wells are numberless; a good account of such will be found in M. L. Fuller, "Domestic Water Supplies for the Farm," Wiley, New York, 1912. A well-borer and drill are illustrated in Fig. 34.

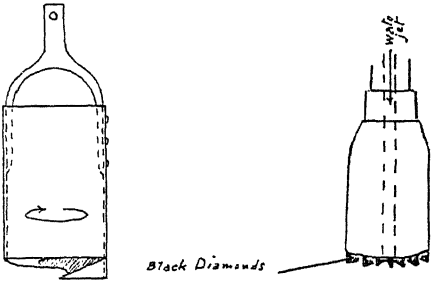

Fig. 34.—Well-Borer and Diamond Drill.

An occasional test of well water is desirable where it is employed for drinking purposes, especially if any colour, turbidity, or unusual taste develops, though sewage pollution would not normally be rendered evident in any such way. The performance of the following simple tests will usually show when such pollution is present, and if any of them yield a positive result a sample of the water should be submitted to an expert for complete examination.

Six drops of a solution of silver nitrate (5 grains to 1 fl. oz. of distilled water) added to half a tumblerful of the water, should yield no turbidity greater than that given by water from a neighbouring source of known purity (absence of chlorides).

A teaspoonful of solution of potassium permanganate (2 grains to 1 fl. oz. distilled water) added to a tumblerful of the water, and two or three drops of strong sulphuric acid then added, should give a bright magenta-coloured solution, the colour of which is not discharged in the course of several days (absence of organic matter).

It should be noted that the presence of organic matter in itself may

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* Including, for purposes of this article, wells of the punched, driven, drilled, and jet sunk types.

WATER AND WATER SUPPLIES (*Continued*)—
not be harmful, but it is frequently a natural concomitant of contamination other than natural and is to that extent always suspect.

No pink colour should appear within ten minutes after adding to a tumblerful of the water half a teaspoonful of acetic acid solution of sulphanilic acid (1½ grains to 1 fl. oz. acetic acid) and the same amount of acetic acid solution of α-naphthylamine (½ grain to 1 fl. oz. acetic acid) (absence of nitrites).

Water may be coloured by vegetable matter in process of decay or by passing through peat, as is the case with the water of Loch Katrine, the purest natural supply in Britain. Turbidity may be due to suspended clay particles and fail to clear on standing. In this case 1 oz. of alum per 60 cu. ft. will usually suffice to effect flocculation and clearing. Objectionable odours are almost always due to otherwise harmless algæ and other microscopic organisms which may be destroyed with copper sulphate; and the same applies to tastes, with the additional possibility that these may be due to minerals, especially iron, the inky taste of ferruginous waters being most characteristic.

Prolonged boiling or treatment with bleaching powder will render any water potable, but where sewage contamination is established the farmer will probably desire a more radical cure, if only on æsthetic grounds.

WATERCRESS (*Nasturtium officinale*)—Watercress is a popular salad plant possessing valuable health-promoting properties. In Great Britain it is particularly popular in the industrial towns and cities of the North and Midlands, although the bulk of the supplies are grown in southern counties. It is estimated that about 1,000 tons of watercress are grown every year, and the demand nearly always exceeds the available supply. The cultivated watercress is the same species as that which grows wild in streams throughout the temperate zone, but the varieties grown are improvements on the wild form.

Varieties—There are two broadly distinct varieties—viz., the **Green** or **Summer** cress and the **Brown** or **Winter** cress. There are also light green and dark green forms of the Summer cress.

Watercress is a lime-loving plant, and flourishes best when grown in the water of springs having their origin in calcareous formations. The majority of the English cultivations are located in the vicinity of the chalk ranges, particularly the North and South Downs and the Chilterns.

Cultivation—As watercress is consumed in a raw, uncooked condition it is of the utmost importance to the industry that public confidence in its safety as an article of diet should be maintained. No one should embark on its cultivation unless he is prepared to observe conditions of the strictest hygiene. Under commercial conditions watercress is always grown in water, and the water employed for the purpose should be absolutely free from any possibility of contamination. To this end it is advisable to make use of natural springs immediately adjoining their location, or, as is done in a good many instances, to use water obtained from special borings, *i.e.*, artesian wells.

WATERCRESS (*Continued*)—

A point of importance in considering the water supply is that it will not be possible to carry on the cultivation of Winter cress without spring water, owing to the fact that the temperature of the latter is always higher and more constant in the winter months than the water of open streams. When using spring water for this purpose it is necessary to keep it covered away from the effect of the air temperature until it actually enters the beds. When boring for water this fact is usually kept in mind, and the bore holes are made close to the site of the beds. On the other hand, water direct from the springs is too cold for the cultivation of summer cress, and it must be warmed up by exposure to the air in reservoirs before it is led into the beds.

Although watercress beds may be constructed on a rough-and-ready plan, it is advisable from the point of view of hygiene to use concrete for the construction of walls, reservoirs, pathways, etc. Beds so constructed can be satisfactorily cleansed at regular intervals without difficulty, and the risk of contamination through drainage, always possible in the case of beds constructed with turf and rough timbers, is considerably reduced. The beds may be laid out singly or in series according to the lie of the land and the supply of water available. A good commercial bed may be from 20 to 30 ft. wide and about ten times the width in length. When in series concrete pathways about 2 ft. wide should be provided. On some of the more elaborate cultivations, light tram lines are laid down on the intersecting pathways on which light trucks to carry off the crops of cress to the packing sheds are run.

The best form of bottom for the beds is gravel, or sand with a chalk subsoil. The water should flow evenly, freely but gently, over the entire bed; there should be no stagnation anywhere. This can usually be arranged with the aid of adequate inlet and outlet pipes, but it is generally advisable to provide a "head" of water at the top end of the bed so that the amount let into the bed at any given time is under full control. Watercress grows in pure water only, and no organic matter or plant food in the form of fertilizers is necessary.

Planting is carried out by scattering thinly on the surface of the prepared beds the tops of fully grown cress from 12 to 18 ins. long. Stock beds to supply the planting requirements should always be provided. The planting of the Brown or Winter cress is usually done during August and September, and the Green or Summer cress during late autumn. The latter will take root and stand the winter, but will not make any appreciable growth until the late spring of the following year. The Winter cress normally takes about four months to arrive at the stage when the first cutting can be taken, and thereafter it will regrow fairly quickly and can be cut at regular intervals until the Summer cress commences to come in.

Marketing—It will be gathered from this short acount of the industry that watercress can furnish a valuable supply of salad food over several months of the year. The bulk of the crop is, however, marketed during the winter and spring months of the year when other salad crops

WATERCRESS (*Continued*)—

are scarce and expensive. Being a perishable crop, watercress has to be marketed with all possible speed. As a rule cutting commences very early in the morning and the day's gathering is despatched in time to reach the market early on the following morning. Although the long established method of marketing the cress in bulk, using wicker flats holding either about 35 lbs. or about 70 lbs. of cress, is favoured, some growers now bunch the cress and market it in non-returnable chip baskets holding three dozen bunches or 7 lbs.

Nutritionally, watercress is the most valuable of all the salad crops as it contains iodine, iron, phosphates, potash, sulphur, in addition to its vitamin-providing properties, and from a health point of view its consumption could be considerably extended with advantage.

WATER-GLASS [Sodium silicate, $Na(SiO_3.9H_2O)$] is soluble in water, and the solution is largely employed in preserving eggs, the shells of which are rendered air-tight by it. In this way ingress of bacteria and of oxygen is prevented, and the eggs are preserved in a very similar way to that in which germ-free meats can be preserved in hermetically sealed tins. Water-glass has other uses in the dyeing, calico-printing, paper, concrete, and other trades.

The presence of sodium silicate in soils is found to have a markedly beneficial effect on the yield of a barley crop, this effect being more noticeable where no superphosphate is used. Fisher (*J. Agric. Sci.*, xix., 132, 1929) ascribes this to its ability to make the phosphorus in the soil available to the plant, but see also the note by Sir A. D. Hall, *ibid.*, p. 586.

WATER WHEELS AND TURBINES—The water wheel is a very old hydraulic appliance for obtaining power from running water. In the course of time two principal types have developed, called, respectively, the overshot and the undershot wheel. The so-called breast wheel approximates more or less nearly to the overshot or undershot, according to the point at which the water is led into the wheel.

The *overshot wheel* is perhaps the one most commonly met with. It consists of an iron or heavy wooden axle, to which stout spokes are fixed to which the sole plate and shrouds (sides of the buckets) are attached. The buckets, of wood or iron, are fixed on to the sole plate and shrouds, their mouths being made about equal to the depth of the shrouds, and the bucket narrowing to about half this. In this way some loss of water by spilling is avoided, but as a further precaution in this matter it is usual to restrict the water supply to about one-third the computed capacity of the buckets by means of a sluice. An apron is also frequently provided at the bottom to keep the water in the buckets for the maximum possible time. Such a wheel provided with wooden buckets (iron buckets are of a different form) is illustrated in Fig. 35.

Such wheels are usually suitable for falls varying from 10 up to as much as 70 ft. If the level of tail water varies much, a smaller wheel must be installed, so that not more than about a foot is immersed at the

WATER WHEELS AND TURBINES (*Continued*)—

highest tail-water level. In cases where the head-water level is variable, it is sometimes necessary to use a different type of wheel, as with the overshot type the water entering the wheel must clearly have a greater velocity than the periphery of the wheel, or it will not enter it at all, and large head variation may make it difficult to fulfil this condition. In such cases a *high-breast wheel* is commonly used. This is similar to the overshot, but works the reverse way round, and water is fed into it over the *top* of an adjustable sluice. If Q is the water supply in cubic feet/second, and v the peripheral velocity of the wheel in feet/second, the breadth, in view of what is stated above, may clearly be $\frac{3Q}{kv}$ ft., where k is the bucket capacity in cubic feet per foot of circumference. The efficiency comes out at about 75 per cent.

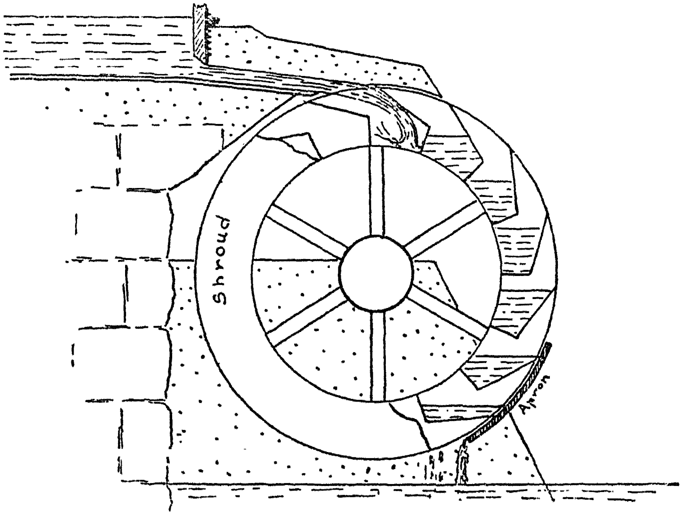

FIG. 35.—OVERSHOT WATER WHEEL.

The power from such wheels is normally transferred to the shafting by a spur or bevel keyed on to the axle, but where the wheel is of the suspended type, *i.e.*, like a bicycle-wheel, the spokes are unsuitable for transmitting the power, and in this case a circular set of cogs is fixed to the shrouds engaging with a pinion at a distance from the centre equal to that of the centre of gravity of the water in the loaded arc of the wheel.

In Fig. 36 is shown the *undershot or Poncelet wheel*. In the overshot type the head water delivers its potential energy to the wheel directly by dragging the circumference of the wheel with it in its fall to the lower level. In the undershot wheel this delivery of energy is indirect, the potential energy being first converted into the kinetic energy of a rapidly moving water stream, and this kinetic energy is then given to

WATER WHEELS AND TURBINES (*Continued*)—

the rim of the wheel as the stream is brought to rest by the "floats" which take the place of the buckets in the overshot type. The construction is otherwise similar. Theoretically, for maximum efficiency—that is, in order that the whole of the kinetic energy of the water stream may be delivered to the float—the curvature of the latter must be such that the water enters tangentially, but, owing to practical difficulties in getting the water out of the wheel, a compromise is adopted, and the floats receive the stream at an angle of about 15°. Only three cells are shown filled with water, but in practice the thickness of stream and breasting are so arranged that about eight cells are usually full at any one time.

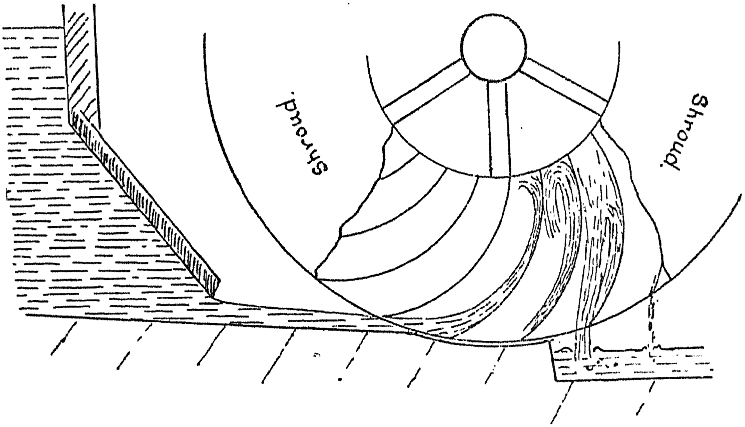

FIG. 36.—UNDERSHOT WATER WHEEL

Undershot wheels are adapted to falls not exceeding 6 ft. It will be observed that the efficiency is likely to be somewhat less than that of an overshot wheel, and this is found to be so in practice, 60 per cent. being a normal figure. Also, such wheels must usually be of large size, 14 ft. being the smallest in common use. The impulse stream is usually about 9 ins. deep, and should not exceed 15 ins. in flood. The radial cell depth should be about half the fall. It is clear that all sorts of gradations of type can be made between the high-breast type and the pure undershot, and many such have been constructed. In both types of wheel the estimation of the horse power that may be expected is the same, since in both the energy available per second in foot-pounds is equal to the weight of water coming into the wheel per second × the fall in feet. Although in the second case this is first converted into energy of motion, it is not altered in quantity. Hence, the brake horse power in each case is given by:

$$\text{B.H.P.} = \frac{\text{weight of water per second in lbs} \times \text{fall in feet} \times \text{efficiency.}}{550}$$

It will be noticed that the water falling out from the floats of an undershot wheel has a certain component of velocity with reference

WATER WHEELS AND TURBINES (*Continued*)—

to the wheel in the direction opposite to that in which the circumference of the wheel is travelling. If this were not so, the water would fall from the wheel with approximately half its original forward velocity, and about a quarter of the original kinetic energy would be wasted in augmenting the speed of the tail race. The efficiency of the wheel is therefore increased by this means, and the idea has been further developed in a series of wheels known as *impulse wheels*, of which the Pelton, Doble, and Escher-Wyss wheels are examples. The principle of such wheels, which form an intermediate stage between the undershot water wheel and the impulse turbine, is that a jet of water is directed on to a bucket so shaped that the water is thrown back from it with a velocity as nearly as possible equal to that with which it strikes it. If this state of affairs could be completely attained, we should then have a jet of velocity (say) $2v$ striking a bucket moving in the same direction with about half that velocity—namely, v; thus the velocity of the jet with reference to the bucket would be v in the direction in which both are moving, and the water would pass out of the bucket with a velocity v in the opposite direction with reference to the bucket. Hence water travelling in the jet would have velocity $2v$, which would be reduced to v, the velocity of the bucket, at the moment when its forward velocity was the same as that of the bucket, *i.e.*, at b, Fig. 37, and this would be reduced to nil as it was projected backwards from the bucket with a velocity equal to the forward motion of the bucket. Thus, all the kinetic energy of the jet would be given to the wheel. In practice this condition cannot be completely attained, partly owing to internal friction, but mainly owing to the necessity of throwing the water out from one bucket so that it passes to either side of the next advancing bucket. The water in the jet is regulated to the quantity conditions required by a needle valve (see Fig. 37). As the splashing is very great, such wheels are always enclosed in some type of casing.

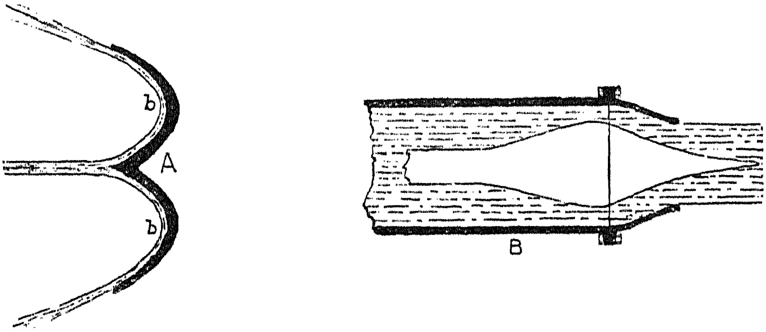

Fig. 37.—A, Bucket of Impulse Wheel; B, Doble Stream-Lined Needle Jet Regulator for Impulse Wheels.

Impulse wheels are very useful where high falls exceeding 100 ft. are

WATER WHEELS AND TURBINES (*Continued*)—

available, and the power may be increased by using two or more jets on the same wheel. The efficiency may attain to 80 per cent. These wheels may moreover be of practically any convenient size, and the needle regulator may, if so desired, be operated by a governor, thus keeping speed sensibly constant at all loads.

The *impulse turbine* does not differ greatly from an impulse wheel in principle. Originally, the name turbine was used only of wheels running in a horizontal plane, with a vertical axle, but as special designs developed for these machines, and these designs were applied to machines with horizontal axles, the name followed them, and it is now used of any machine in which these details of design are incorporated. In the impulse wheel one or several jets play upon the wheel buckets or vanes; water being led to the jets by separate pipes or penstocks. In the impulse turbine and water turbines generally the water is led to a strong casing surrounding the wheel, and provided with guides to direct the water on to the wheel vanes at the proper angle for the avoidance of shock and development of greatest efficiency. There can, however, be no hard-and-fast line drawn between the two; the Girard turbine, for example, although partaking of the general design of turbines, would here be classified as an impulse wheel.

The *reaction turbine* differs from the impulse turbine in that, while in the latter the water passes to the vanes with the whole of its energy in the form of kinetic energy, and passes out from the vanes, the spaces of which are never filled, to an outlet chamber partially filled with air, in the former the whole machine is filled with water, a portion of the energy being transferred to the vanes in the form of pressure energy. Such turbines are often run completely immersed in the tail water.

Both types are made in a variety of designs. The water may flow from the periphery to the centre (inward flow) or *vice versa* (outward flow); or, again, the water may enter one end of a large pipe, to which the guide vanes are fixed, containing the journal and drum with the movable vanes, which are turned by the water in flowing along the pipe between the guides (axial flow type). Sometimes twin turbines are mounted on the same axis for better balancing, and when the waste water from one is used to drive the other, the machine is called a compound turbine. A type of some interest to the farmer is the limit turbine, which runs as an impulse turbine, but if the tail water rises too high and drowns it, it transforms itself into a reaction machine without appreciable loss of efficiency.

In impulse turbines the water supply is usually controlled by a system of sluices operating on the passages between the guides, by which the admission of water to the wheel is restricted to a part of the periphery allowing, however, complete admission when required. In reaction machines the admission must always be complete, or the efficiency falls rapidly owing to the energy lost in continually starting and stopping the flow of water in the cells of the wheel. Such turbines run too fast on high falls, and, generally speaking, the impulse turbine is better suited to high falls, and the reaction machine to low falls, as in these cases variation of head is common, and impulse machines then

WATER WHEELS AND TURBINES (*Continued*)—

fall rapidly in efficiency. Where speed constancy is of importance, as in driving dynamos, the reaction type is better, and should be arranged with axial flow if the head varies, otherwise an inward flow type should be selected, as then the centrifugal head assists in the maintenance of constant speed, since any increase in speed of rotation tends to check the flow of water through the wheel, and *vice versa.*

Both efficiency and convenience may be served in the case of a reaction turbine by fixing it well above tail water level, and attaching a draft tube to the exit which acts as a water pump, reducing the pressure in the outlet chamber. The losses in such a draft tube are less than normally encountered in direct discharge into tail water.

Fig. 38 shows how the water passes on to the vanes in starting up an impulse turbine of the kind stated. It will be noticed that the angle of the vane as the water enters the wheel does not correspond to the angle of delivery from the guide vanes. This angle, however, is so computed that when the wheel is rotating in the direction of the arrow at the normal speed for which it is designed, the water shall enter the wheel without shock. It is easy to understand in a general way how this happens. Consider the points *a* and *b* on a vane: the water reaches the point *a* first and takes a small but appreciable time to reach *b*, but in this short space of time the revolution of the wheel has carried the point *b* to some point *b′*, so that the effective receiving surface of the vane has the direction *ab′*, and the water enters from the guide vanes without shock. Speaking generally, the efficiency of a water turbine suited to its work may be from 78 to 81 per cent.

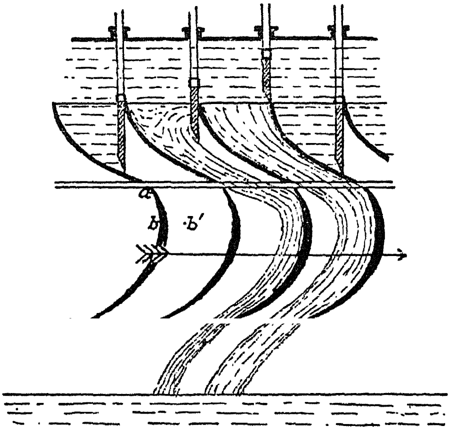

Fig. 38.—Vertical Tangential Section through Vanes and Guides of Axial Flow, Partial Admission Impulse Turbine showing Guide Passage Sluices.

In *steam turbines* certain differences of design are incorporated owing to the fact that an expansible fluid is the source of power. Notably a large number of successive rings of guide vanes and turbine blades are employed, the expansion of the steam taking place from one to the other in successive short stages. Such turbines are frequently employed compounded, and the axis of rotation is almost always horizontal (vertical in separators). The nozzle delivering the steam to the turbine is often of special form, being stream-lined down to the narrowest part and then expanding to the orifice, as the velocity increase is at first the predominant factor, and afterwards the volume expansion acquires a preponderating influence. In this way adiabatic expansion is

WATER WHEELS AND TURBINES (*Continued*)—

made possible with concomitant economy of energy. If the expansion were not arranged to take place in short stages, it would be necessary, to secure the best efficiency, to arrange for a wheel with a peripheral velocity considerably above that which could be tolerated by any wheel constructed on present methods, and the wear on the blades due to steam striking them at a relative velocity approximating to 2,000 ft. per second would wear them out in a very short time.

For further particulars and more advanced treatment the following works may be consulted: H. J. Hughes and A. T. Stafford, "Hydraulics," Macmillan, New York, 1911; A. H. Gibson, "Hydraulics and its Application," Constable, London, 1925; F. Johnstone-Taylor, "Water Power Practice," Crosby Lockwood, London, 1927; J. A. Moyer, "Steam Turbines," Wiley, New York, 1929; T. W. Naylor, "Steam Turbines," Chapman and Hall, London, 1929; and articles "Water Motors," "Hydraulics," and "Steam Engine" in 12th edit. Encyclopædia Britannica.

T. D.

WAXES—The waxes met with in commerce are very numerous, but they may be roughly divided into two classes: (*a*) those of mineral or apparently, mineral origin; (*b*) those of vegetable and animal origin. The former consist almost entirely of hydrocarbons of high molecular weight, and are obtained from the oily distillates from bituminous substances such as shale, lignite, ozokerite, bituminous coal, crude petroleum, etc., partly by refrigeration and partly by centrifugal deposition from cracked oils. These products are all white translucent waxes, melting at temperatures from 45° to 65° C., and are known as *paraffin wax,* usually without distinction as to origin. They are used in the manufacture of candles, floor polishes, waxed paper, as lubricants, etc. The vegetable and animal waxes are of more interest to the agriculturist, and foremost of these stands *beeswax,* a yellow, tough solid consisting to the extent of 85 per cent. of myricyl palmitate, the yellow colour being due to resinous substances in the plants the bees visit. It is used for modelling compositions, candles, polishes, and in the engraving trades. The remaining vegetable and animal waxes are mixtures of esters of monohydric alcohols with fatty acids of high molecular weight, and the number of kinds are very large. Of these the following may be mentioned as of some interest to the farmer. *Cotton-seed wax* is contained in raw cotton to the extent of about three-quarters of 1 per cent. *Flax wax* is a dark green or brown hard wax, taking a high polish. *Wool wax* (lanoline), obtained from "suint," is used for soap making, and in ointments and cosmetics. It consists largely of cholesterol. *Montana wax,* extracted from peat, has a high melting point, 76° C. There is also mineral wax sold under the same name obtained from lignite. *Sugar-cane wax* is a hard wax analogous to beeswax in composition, and sometimes used as a substitute for this. It is extracted from the scum of the "boil" or from the dried filter-press cake. *Bog wax,* found in Ireland and other places, is an interesting type occurring in fair-sized lumps in the peat bogs. It may very possibly be identical with *adipocere* or *corpse wax,*

WAXES (*Continued*)—
which is formed under some conditions from human and animal remains. The fatty tissues appear to become cerified in a way not definitely understood. It is of common occurrence in some cemeteries.

WEEDS—In the introduction to an essay entitled "Weeds of Agriculture," by Benjamin Holdich (edited by George Sinclair and published about 1825), the following passage occurs: "It seems also somewhat strange, at this advanced period of agricultural knowledge, that so many queries should be put, "How to destroy blackgrass?" "How to destroy coltsfoot?" etc., as if there were any secret known to a few, or any charm in existence, by which an overwhelming increase of any particular weed could be stopped at once. But the world is always in a state of pupilage; some are learning what others know; and the queries which to the young are interesting, are to the experienced and wise trifling and superfluous."

It is remarkable that even at the present time, a century later, large numbers of questions are still asked as to the destruction of many weeds, but a great many more species are nowadays recognized as at least occasionally troublesome. An essay by W. Pitt, published in 1806 in the Communications to the Board of Agriculture, appears to list only fifty-five weeds, but it would not be difficult to name well over 300 species, of which perhaps 100 at least are occasionally seriously injurious. This may perhaps be demonstrated by stating that about twenty years ago the writer invited a number of authorities in different parts of Great Britain to state what they considered to be the six worst weeds of arable and grass land respectively in their neighbourhood. As regards arable land, an examination of the replies indicates that in twenty-nine returns the following species are mentioned the number of times stated:

		No. of Times.
Couch or twitch*		32
Charlock and runch		28
Docks		16
Thistles		16
Coltsfoot		13
Chickweed		9
Bindweeds		8
Spurrey		7
Poppies and corn buttercup ("burrs" or "scratch burrs")	each	6
Wild oat		5
Knotweed and fat hen	each	4
Redshank		3
Groundsel, fumitory, corn marigold, *Alopecurus agrestis*, *Poa annua*, and nettles	each	2
Self-heal, herb gerard, hemp nettle, wild mint, mayweed, cleavers, horsetail, speedwell, broom-rape, dodder, pepperwort, wild carrot, yellow toadflax, shepherd's purse, annual knawel, speedwell (*Veronica agrestis*), mugwort, wart cress and thale cress	each	1

---

* Including *Triticum repens*, *Agrostis* sp., and *Arrhenatherum avenaceum*, var. *bulbosum*, as these are all termed twitch, wicks, wickens, couch, etc. Two of these species were, however, given in some returns, and these are included in the figures quoted.

WEEDS (*Continued*)—

In the same number of returns referring to grass land, an analysis shows that the following species were mentioned the stated number of times:

	No. of Times.
Thistles	22
Buttercups	16
Holcus lanatus and *H. mollis*	9
Docks	8
Daisy	7
Plantain	6
Soft brome	6
Yellow rattle, sorrels, dandelion, *Agrostis* spp. each	5
Knapweed, rushes, nettles each	4
Ragwort, hassock grass, rest harrow each	3
Moss, self-heal, sedges, hawkweed (*Hieracium*), bracken, mountain flax, scabious, meadow saffron each	2
Sweet vernal, rough-stalked meadow grass, mouse-ear chickweed, couch, ox-eye daisy, pig nut (*Conopodium*), cow parsley (*Petroselinum*), meadow barley grass, cat's ear, corn marigold, stinking mayweed, wild carrot, cowslip, broom, gorse, dyer's green weed, silver weed each	1

These statements show that, taking the twenty-nine returns, the average " degree of badness " is indicated by the number of times the species are mentioned. Although he must be a poor farmer indeed who does not recognize the injurious character of weeds in relation to his crops, it is very desirable that one should be quite clear as to the nature of the damage done. It is not merely that weeds rob the crop of the food that is intended for its use, but they also steal moisture, and, in addition, by crowding the crop deprive it of air, light, and the warmth of the sun during the height of the growing season. Every grower of plants knows that if seedlings stand too thick in the rows they will grow lank and "weedy," and that the individual plants will be almost unproductive if they are not given more space by thinning. The forester recognizes the same fact in relation to forest trees—the closer the growth the thinner and taller the stem; an oak standing by itself in a park will spread its boughs over a considerable distance and may not be very tall, but grown under the conditions of high forest in close competition with many fellows it produces a tall, straight bole, comparatively free from side branches. In all these cases—garden crops, field crops, forest crops—there is a point at which the competition will prove injurious. On the farm the point is, perhaps, most often reached owing to the intense competition of large quantities of weeds.

Quite apart from the competition for plant food, moisture, light, and air, weeds hinder the ripening, drying, and harvesting of corn crops; they greatly increase the expense of singling and growing root and similar crops; they act as hosts for insect and fungus pests; certain of them taint the milk or meat produced by the animals which eat them; many are poisonous to stock; some are parasitic or semi-parasitic, and directly live upon their host; and in some cases the

WEEDS (*Continued*)—

underground roots and creeping rootstocks of some species increase the cost of cultivation and may stop drains.

In view of the foregoing statement on the damage done by weed infestation, it will be the better understood that the presence of weed seeds in samples of crop seeds detracts considerably from the value of the latter.

The number of weed seeds in the soil is astonishingly high; careful investigation has shown that they may amount to very many millions per acre, and this fact affords convincing evidence of the extent to which weeds themselves may overwhelm a cultivated crop. The financial loss that may be due to the presence of weeds is not readily estimated in any particular case, but experimental work has shown that in certain instances the loss may easily be 50 per cent. of the value of the crop—that is to say, that the crop is not more than one-half of what it should be. In individual cases the loss may be much more. It was estimated before the War that the loss due to reduction in crop and to labour expended in the suppression of weeds in Great Britain was about 16½ millions sterling per annum. There can be little doubt that it is now much above that figure.

A point of importance in relation to weed eradication is a knowledge of the manner in which weeds are distributed. Leaving detail to be filled in by the imagination of the reader, it may briefly be stated that nature provides for the dissemination of plants by natural seeding, by broken portions of the root, or by other parts of the plant. In the case of farm weeds, the distribution is by seed, or, where many perennials are concerned, through broken pieces of the root or underground stems also. In either case the distribution of seeds may be secured by many agencies. Seeds are blown by the wind; are carried by birds and animals; are washed long distances by rivers, streams, and floods; are transported and sown with agricultural seeds; are carted to the fields in farmyard manure, and in screenings from thrashing machines; they may also be carried on farm implements and machinery —such as thrashing machines, self-binders, carts, and even in the mud on wheels. Portions of creeping rootstock may be distributed in many ways—on farm machinery, in farmyard manure, and even on the boots of workers. In connexion with the distribution of weeds, it should also be borne in mind that the number of seeds produced by individual plants is often very great, from a few hundred (as in the case of corn cockle or field bindweed) to many thousands (as in the poppy or the corn marigold), or even 100,000 or more in certain other species.

It is, of course, to be recognized that, in the ultimate, weeds might generally be correlated with certain soils—that is to say, the various species of weeds appear to have a partiality for definite types of soil. So much is this true, where many species are concerned, that they actually serve as indicators of soil type or soil condition. It is commonly recognized, for example, that rushes, horsetails, tussock grass, butter bur, meadow sweet, and lady's smock are fairly certain indicators that the soil on which they are growing is damp and badly

WEEDS (*Continued*)—

drained; that Yorkshire fog, ox-eye daisy, quaking grass, rest harrow, and sheep's sorrel indicate soils in a poor state of fertility; that the corn marigold, sheep's sorrel, bracken, and spurrey only occur at their best in soils deficient in lime; and that the stemless thistle, chicory, viper's bugloss, and bladder campion occur naturally on calcareous soils.

Suppression of Weeds—When one comes to consider the question of weed eradication, the first point to bear in mind is the old adage that "Prevention is better than cure," while another proverb that deserves special recollection is the saying that "One year's seeding is seven years' weeding." The implication is clear: in the case of the vast majority of weeds the complete prevention of seeding will be sufficient to reduce very rapidly the incidence of weeds in the field concerned. This applies with particular force where annuals and biennials are involved, but much less so in the case of the perennials or "root" weeds. These last possess the second means of propagation, and even though they may be effectively prevented from seeding, will, if they retain their leaves, store up food in the rootstock for the purposes of growth in the following season. With perennials, therefore, the prevention of seeding must not be regarded as sufficient; it is necessary to exhaust the reserves of food in the rootstock by repeatedly cutting the plant, thereby removing the leaves, which serve to feed it. Repeated cutting of this kind induces the rootstock to throw up fresh shoots in an endeavour to produce flower and seed, and each removal of the fresh growth further exhausts the underground parts.

Bearing these general principles in mind, it may be said briefly that preventive and remedial measures should include:

1. All such measures as will prevent the distribution of weed seeds —such as cutting of the weeds in a variety of ways and by tillage operations; the use of pure seed free from weed seeds; destruction of weeds in some cases by spraying; and cleanliness in relation to such farm machinery as self-binders, thrashing machines, and carts at harvest time.

2. Thorough tillage, involving the variety of operations usually practised in arable cultivation, such as ploughing, cultivating, hoeing, and harrowing, and in many cases the hand collection and burning of root weeds, such as couch, bindweed, etc. Except on very clean land, care should be taken to drill seed sufficiently widely to permit of both horse- and hand-hoeing. Disking or light scarifying after harvest will encourage the germination of many weed seeds, the young seedlings from which will be destroyed by subsequent ploughing. Similarly, judicious spring tillage with repeated surface cultivations will be responsible for the destruction of millions of seedlings during the spring months.

In relation to tillage, bastard or bare fallowing may be desirable on the very heavy classes of soil.

The taking of "cleaning crops," such as roots, potatoes, drumhead cabbage, and so forth, will all go far in the direction of weed eradication,

WEEDS (*Continued*)—

particularly if they are specially regarded as cleaning crops and are accordingly dealt with faithfully. In this connection it may usefully be borne in mind that experiments with mangolds at Reading over twenty years ago showed that a single hoeing almost doubled the yield (31 tons) as compared with no hoeing (16¼ tons), while a second hoeing further greatly increased the yield (37¼ tons). It will naturally be understood that practical tillage operations must depend on such factors as the type of soil, the rotation, climatic conditions, and so forth.

3. The suppression of weeds by the means of dense growing " smother " crops is often particularly valuable—crops useful for the purpose being mustard, rape, marrow-stem kale, buckwheat, maize in the south, and various mixtures of vetches or peas with oats or rye.

Feeding of sheep on arable land, where possible, may be useful.

4. Matters which deserve special attention are draining, liming, and manuring. If liming and manuring are to be as effective as they should be, good drainage is essential. In many cases it would seem that heavy liming is almost a specific against spurrey, sheep's sorrel, and corn marigold.

The improvement of the fertility of land, inasmuch as it brings on the sown crop rapidly and enables it to outgrow the undesirable weed flora, must be regarded as a defence against weeds.

5. Certain weeds of arable land may be combated by spraying corn crops containing them with solutions of copper sulphate, iron sulphate, or sulphate of ammonia, or by " dusting " the cereal crop with calcium cyanamide or finely ground kainit. Copper sulphate may be used as a 4 or 5 per cent. solution, 40 gallons to the acre (16 or 20 lbs. in 40 gallons). Iron sulphate may be used as a 15 per cent. solution (60 lbs. in 40 gallons). Sulphate of ammonia may be tried at the rate of from 1 to 2 cwts. in 60 gallons of water per acre. Calcium cyanamide should be used at the rate of 1 or 2 cwts. per acre. Kainit is applied at the rate of 4 to 6 cwts. per acre, when the dew is on the leaf and the seedlings, especially those of charlock, are in the seedling stage.

Weeds in Grass Land—A special word is desirable in regard to the weeds of grass land. In the large majority of cases weeds of grass land are not found also in arable, although there are certain exceptions —as that of the creeping thistle, which is prolific in both. The method of control is naturally different. In a number of instances, such as those of yellow rattle and Yorkshire fog, the weed species are annuals, and seeding is liable to occur at or about the usual hay season. To combat such species, therefore, mowing should take place rather earlier than usual, and if this is done two or three years in succession, seeding is prevented and the weeds are greatly reduced. Where perennials are concerned, the running of the mowing machine over grass land two or three times during the summer months will have a very beneficial effect in reducing the weed flora—as holds true for the creeping thistle (*q.v.*).

WEEDS (*Continued*)—

The question of the improvement of grass land has been the subject of extensive investigations during recent years, and it is desirable to state that points that need special consideration in this connection are drainage, liming, the use of fertilizers, close grazing with different classes of livestock, harrowing, or even heavy dragging, and the use of the mowing machine to remove tufted growths or foggage. Management of grass land that takes into consideration the foregoing points may be regarded as certain to bring about considerable improvement of the herbage of grass land. A point of some importance is that grazing should not be confined to one class of livestock, since horses, cattle, and sheep graze differently, and may be held mutually to assist one another in keeping down all classes of herbage. In any case very considerable improvement of poor and weedy grass land may safely be expected when treatment and management are improved.

It is desirable to suggest here that, under the improved conditions of judicious manuring, grazing, and close cutting, a number of the lowlier weeds of grass land may be found to possess a better nutritive value than has hitherto been recognized. Information on the point is not yet definite, but as the nutritive value of grass and other herbage is dependent on leafiness and on its age, it is likely that the same condition will apply also in the case of many weeds, *e.g.*, yarrow, ribwort plantain, but only so long as they are unable to attain the woodiness of maturity.

Scheduled Weeds—The Corn Production Acts (Repeal) Act, 1921, gives the Minister of Agriculture power to serve on occupiers of land infested with certain injurious weeds a notice, in writing, requiring them to cut down or destroy the weeds in the manner and within the time specified in the notice; unreasonable failure to comply renders the occupier liable on summary conviction in respect of each offence to a fine not exceeding £20, and a further fine, not exceeding £1 per day, while default continues after conviction. The Minister's powers under this Act have been delegated to County Agricultural Committees. The weeds to which the provision applies are spear thistle, creeping or field thistle, curled dock, broad-leaved dock, and ragwort. The latest return of the number of cases in which action has been taken to enforce the regulations in England and Wales are for the year 1930, and show a marked increase, the figures being about 19 per cent. above those of 1929. A very large proportion of the cases, however, are dealt with by arrangement: of 5,452 cases reported 5,150 were settled by arrangement, notices were served in 302 cases, and there were 10 prosecutions, all of which were successful.

Having considered weeds generally, certain of the more troublesome species found in arable and grass land may be mentioned.

ARABLE LAND—

Ranunculaceæ.

Buttercups—Two species of buttercups are troublesome on arable land—the creeping buttercup (*Ranunculus repens* L.) and corn

WEEDS (*Continued*)—

buttercup (*R. arvensis* L.). The former must be dealt with by tillage methods applicable to a creeping perennial, and the latter by methods suitable in the case of annuals.

Papaveraceæ.

Poppies—Two species, corn coppy (*Papaver Rhœas* L.) and the smooth-headed poppy (*P. dubium* L.), are fairly widely distributed, and one or other may occur in enormous quantities on certain classes of land. They must be dealt with by frequent surface tillage to encourage germination of the seeds and destruction of the seedlings.

Cruciferæ.

Charlock (*Sinapis arvensis* L.) is perhaps the worst annual weed of arable land. Apart from control by tillage suitable to an annual, the most certain method of dealing with charlock is spraying, when the seedlings are in the young stage, with a solution of copper sulphate as indicated above.

Wild Radish or Runch (*Raphanus Raphanistrum* L.)—In some districts this species is more plentiful than charlock, to which it is closely allied. It may be combated by the same tillage methods as in the case of charlock, but it is less readily damaged by spraying.

Hoary Pepperwort—In recent years this species (*Lepidium draba* L.) has come to be regarded as a dangerous weed pest in certain of the eastern counties, especially Essex, Herts, and Kent. It is the more dangerous because it possesses an extensively creeping, deep-seated rootstock which gives it great powers of resistance to control by the usual methods. It has already appeared in many counties, and should be vigorously attacked and destroyed wherever it is found. Apart from general methods of weed destruction already indicated, spraying has promised to provide a useful method of reducing it. The spray now recommended as the result of experiments in Kent is a solution of 32 to 40 lbs. of copper sulphate in 80 gallons of water, while the use of a spray consisting of 2 cwts. of sulphate of ammonia in 60 gallons of water has also been successful in reducing the weed. It appears, however, that spraying must be repeated if it is to be really successful.

Caryophyllaceæ.

Corn Cockle (*Agrostemma Githago* L.)—This annual or biennial weed of cornfields is found on a variety of soils and may on occasion prove very troublesome. If the seeds occur plentifully in wheat samples there is some possibility of animal poisoning if the wheat is fed to stock. This weed may be combated by tillage methods commonly practised against annuals and biennials.

Spurrey (*Spergula arvensis* L.) sometimes occurs in great excess on light, sandy lands—so abundantly in fact that both corn and root crops may be completely smothered by it. It may be combated by the usual surface tillage operations for killing quick-growing annuals; in some crops it may be destroyed by spraying with a 5 per cent. solution of copper sulphate; and thorough liming is regarded as almost a specific cure. In bad cases it may be grazed off with sheep.

WEEDS (*Continued*)—

Geraniaceæ.

Cranesbills—Two species of cranesbill, or wild geranium, are common and troublesome weeds of arable land—cut-leaved cranesbill (*Geranium dissectum* L.) and dove's-foot cranesbill (*G. molle* L.), both annuals. The seeds of the former are a very common impurity in the seeds of English red clover, trefoil, and crimson clover; while the seeds of the latter are equally troublesome in white clover seed. Every endeavour should be made to keep them down by the taking of hoed crops, and by bodily removal from leys which it is intended to reserve for seed. (See Seeds and Weeds Act.)

Rosaceæ.

Silver-Weed (*Potentilla anserina* L.)—This weed, often known as goose grass, is sometimes a very troublesome pest on arable land that is inclined to be damp. It is a perennial that rapidly covers the ground by means of long runners, broken pieces of which readily root at the nodes. If it once gets a hold it must be combated by vigorous tillage operations, and if necessary by fallowing the land.

Umbelliferæ.

Shepherd's Needle (*Scandix pecten-veneris* L.), *Wild Carrot* (*Daucus carota* L.), and *Fool's Parsley* (*Æthusa cynapium* L.) are occasionally very troublesome on arable land. All may be combated by thorough hoeing of root crops.

Compositæ.

Creeping Thistle (*Cirsium arvense* Scop.) is one of the outstandingly troublesome weeds of arable land, and a related composite which is almost equally troublesome in certain districts is the corn sow-thistle (*Sonchus arvensis* L.). Both are perennials with deep-seated rootstocks, and have the benefit of a long period of growth in winter corn. They can only be successfully combated by frequent and persistent cutting as fast as they attain a few inches growth; such cutting has the effect of reducing the accumulated stores of material in the roots. The eradication of both on arable land is likely to be facilitated by general improvement of the tilth, such as is brought about by draining and liming, the roots being then more readily removed and destroyed during tillage operations, and especially during a bare fallow.

Coltsfoot (*Tussilago Farfara* L.) is a frequent cause of trouble on stiff, damp soils. As a perennial with an extensive creeping rootstock which enables it to extend rapidly, and with large leaves which readily suppress the young plants of any crop in which it appears, it is very desirable that it should be eradicated. Vigorous tillage operations are essential; the flowers should be destroyed when they appear in February and March; the leaves should be removed whenever they appear; in cases of severe infestation a bare fallow may be necessary. It is very desirable to improve the soil texture and to manure thoroughly so that the crop may be encouraged to the fullest extent. Draining may assist in eradicating this moisture-loving plant.

Mayweeds and Chamomiles (*Anthemis* spp. and *Matricaria* spp.)

WEEDS (*Continued*)—

are mainly annual or biennial cornfield weeds which must be combated by preventing seeding by means of surface tillage, thorough hoeing, etc.

Corn Marigold (*Chrysanthemum segetum* L.) is an annual weed of cornfields on loamy and sandy soils, sometimes exceedingly troublesome, possibly because of the vitality of the seeds, which are believed to lie dormant in the soil for considerable periods. Thorough tillage, surface cultivation, and hand pulling are all important; a heavy dressing of lime is regarded as a certain means of reducing the weed.

Convolvulaceæ.

Bindweeds are often particularly troublesome in cornfields and certain other arable crops, not only in view of their smothering action, but because they are climbing weeds that use the cultivated crop as a mechanical support, and in the case of corn crops make harvesting and "conditioning" difficult, especially in wet seasons. The species are great bindweed (*Convolvulus sepium* L.) and field bindweed (*Convolvulus arvensis* L.). The former is more troublesome in garden cultivation than in the field; the latter is often extraordinarily prolific and may cause great loss of field crops. Both are perennials with deep-seated rootstocks, and must therefore be combated by a thorough system of tillage and cleaning.

Dodder (*Cuscuta trifolii* Bab.) is a somewhat remarkable plant of this order which is parasitic upon red clover, lucerne, and certain other plants. It consists of reddish, thread-like leafless stems, producing many clusters of minute, bell-shaped flowers. Wherever a patch of crop is found to be infested with dodder the whole should be cut and burnt upon the spot, or the pest is likely to spread rapidly in all directions. Under the terms of the Seeds Act, 1920, the presence of dodder seeds in clovers, lucerne, and linseed must be declared if above a certain quantity. (See Seeds and Weeds Act, 1920.)

Labiatæ.

Corn or Field Mint (*Mentha arvensis* L.) may prove very troublesome on damp arable land. It is a perennial having extensive creeping rootstocks which serve to distribute it rapidly. It may be reduced by sound tillage, thorough cultivation of fallow crops, the use of smother crops, and by drainage and liming.

Chenopodiaceæ.

Goosefoot or Fat-Hen (*Chenopodium album* L.), and the two species of *Orache, Atriplex patula* L. and *A. hastata* L., are three annuals which may occur in great quantity among fallow crops on soils in good condition, particularly perhaps sandy loams. General measures suitable in the case of annuals will reduce these weeds if thoroughly practised, but if the weeds once get established in fallow crops or even in "seeds" hand pulling may be essential to preserve the crop and prevent seeding.

Polygonaceæ.

Docks (*Rumex* spp.) must be dealt with in arable land by collection and removal during tillage operations; by hand pulling whenever possible; and by repeated spudding or cutting off at the ground level

WEEDS (*Continued*)—

in order to prevent seeding and to exhaust the stores of food in the rootstock.

Persicaria or Redshank (*Polygonum persicaria* L.) is frequently troublesome on soils in good condition. It is an annual, and may be dealt with by cultivations applicable to similar seed weeds; it may also be greatly reduced by spraying with a 4 per cent. solution of copper sulphate, when conditions admit.

Knotgrass or Knotweed (*Polygonum aviculare* L.) is a common annual weed often occurring in amazing quantity on the lighter soils, flowering throughout the summer, and producing enormous quantities of seed. Thorough tillage with frequent surface cultivations, and increased fallow crops faithfully hoed, will be necessary to prevent this weed from seeding and so reduce it.

Black Bindweed (*Polygonum convolvulus* L.) is a prostrate or climbing annual which grows with great rapidity and overruns both cereal and other crops. In the former it may shed large quantities of seeds, many of which may be shaken out in carts during harvesting or be included in screenings when the corn is thrashed; in the latter case they should be destroyed, or be ground or boiled before they are given to stock. Spring and autumn surface cultivation and well-hoed crops are indicated as means of reduction.

Urticaceæ.

Nettles (*Urtica dioica* L. and *U. urens* L.) are often troublesome, particularly the former species, which is a perennial with a creeping rootstock. Patches of it should be removed with a fork unless they are too large, in which case thorough tillage, with collection and burning of the weed, and the taking of well-hoed fallow crops, will be necessary. A dressing of 6 cwts. of salt may be helpful, and a trial patch may be so treated. *U. urens* is annual and may be dealt with accordingly.

Liliaceæ.

Wild Onion (*Allium vineale* L.) often occurs in enormous quantity in certain districts, and in view of its method of reproduction and its great vitality it can only be reduced with the very greatest difficulty. The bulbs increase in much the same way as the ordinary onion, while the flower heads give rise to large quantities of bulbils or bulblets about the size of wheat grains. In arable land thorough cultivation of two root crops in succession and the growing of heavy smother crops may help considerably in reducing this weed, which has been fully dealt with in a publication of the Ministry of Agriculture.

Gramineæ.

Slender Foxtail, known also as hungerweed or black bent (*Alopecurus agrestis* L.), is an annual grass closely related to, and somewhat resembling, meadow foxtail, the spike, however, being more slender and somewhat rough. It seeds freely and has been regarded as difficult to eradicate. It seems, however, that by means of surface cultivation the seeds may be encouraged to germinate immediately after harvest, so that great numbers of the young seedlings may be ploughed down with the stubble. There is also experimental evidence

WEEDS (*Continued*)—

which suggests that ploughing to a depth of 9 inches in autumn is likely to result in the destruction of most of the seed ploughed down.

Couch or Twitch—It will be convenient to include under this head three species of grass—true couch (*Agropyrum repens* Beauv.; *Triticum repens* L.), common bent grass (*Agrostis vulgaris* With.), and onion couch or bulbous oatgrass (*Arrhenatherum avenaceum* Beauv. var. *bulbosum* Lindl.). The first of these has extensive creeping, underground stems of the thickness of a steel knitting-needle, and bears tall, strong flowering stems with spikes superficially resembling those of rye grass, although, relative to the rachis, the spikelets are arranged in the same manner as those of an ear of wheat.

Common bent is much more slender in habit, with rather fine creeping stems which lie on or just beneath the surface of the ground—not deeply seated as in the case of true couch. The flower heads are slender, fine-branched, spreading panicles.

Onion couch closely resembles ordinary tall oat grass, but is peculiar in producing swollen internodes just beneath the surface of the ground on its slightly creeping rootstock. These internodes are about the size of a large pea, and several are commonly joined together somewhat after the manner of a string of beads.

All three of these species must be combated by tillage operations and by the collection and burning of the rootstocks. Any treatment to ameliorate the soil, *e.g.* liming, will enable them to be removed more easily and effectively. On some soils occasional bare fallowing may be necessary to reduce these weeds. The laying down of land to grass for a period may result in the disappearance of true couch.

Wild Oat Grass (*Avena fatua* L.) is often troublesome, particularly in corn crops. It is important that only pure seed grain should be sown. The grain of the wild oat does not germinate readily in the autumn, and shallow cultivation at this time is calculated to assist in this direction. When once germinated the seedlings may be destroyed in the spring by ordinary cultivation and harrowing. A root crop should follow on badly infested land, and in extreme cases a crop of peas and oats, or tares and oats, may be taken for conversion into hay; the wild oats in these crops will be immature when cut and simply increase the yield of hay.

Equisetaceæ.

Horsetails (*Equisetum* spp.) of various species are widely distributed in Britain, both in arable and grass land. In arable land they can best be combated by ensuring thorough drainage, followed by liming, deep ploughing, and thorough tillage, together with the taking of root crops and such smother crops as vetches and rape.

GRASS LAND—Among weeds of grass land a few deserve special mention, but the fact that methods directed to improve the general condition of such land—drainage, scarifying, liming, manuring, grazing, and management generally—will steadily effect a reduction in the weed flora, should be kept ever in mind. Wild white clover should everywhere be encouraged if already present, otherwise it should be sown.

WEEDS (*Continued*)—

Caryophyllaceæ.

Mouse-Ear Chickweed (*Cerastium vulgatum* L.) may occur in abundance, particularly on grass land in poor condition. Fream found it in forty-nine out of eighty turves from various districts. Improvement of the herbage generally will automatically lead to a reduction of this weed.

Leguminosæ.

Gorse (*Ulex europæus* L.) and related species, widely known also as furze or whin, occurs extensively on moorlands and poor pastures in many parts of the country. It may be reduced by grubbing or burning, according to the size of the shrub, in dry weather, following this by re-seeding the bare patches, manurial treatment, and sound grazing.

Broom (*Cytisus scoparius* Link.) occurs in much the same situations as gorse, and may be dealt with in the same manner.

Dyer's Greenweed (*Genista tinctoria* L.) is sometimes very troublesome on poor, heavy land pastures. It should be combated by regular cutting and by improvement of the grass land, especially by the use of phosphates.

Rest Harrow (*Ononis spinosa* L.) is a hairy perennial often plentiful on poor, heavy land pastures. It may be combated by regular cutting, manurial treatment, close depasturing.

Compositæ.

Knapweed or Hardheads (*Centaurea nigra* L.) is far too common in pastures and meadows on the heavier and calcareous soils, especially those in poor condition. It is a useless perennial. It will be reduced by the ordinary methods adopted for the improvement of grass land—early cutting to prevent seeding, manurial treatment, close depasturing.

The Creeping Thistle (*Cirsium arvense* Scop.) is one of the most troublesome weeds of grass land, but may be successfully reduced by cutting three times a year during the summer months for about three years.

The Spear Thistle (*Cirsium lanceolatum* Scop.) is a biennial which may be reduced by preventing seeding—either by spudding the rosettes in autumn and early spring or by cutting the half-grown plants.

The Stemless Thistle (*Cirsium acaule* Scop.) is a perennial often very plentiful and injurious on poor calcareous hill pastures. Owing to its lowly growth, the flower heads being scarcely pushed beyond the flattish rosette of leaves, it can hardly be met other than by spudding, and by general improvement of the herbage by manurial treatment and the sowing of wild white clover.

Ox-Eye Daisy (*Chrysanthemum leucanthemum* L.) is a well-known perennial weed of poor clays and calcareous loams. Early cutting for hay to prevent seeding, combined with liming, manurial treatment, and depasturing, will serve to reduce it.

Ragwort (*Senecio Jacobæa* L.) is a biennial or perennial of poor pastures, often extremely plentiful. The general improvement of the pasture, combined with regular cutting, will greatly reduce it, and its

WEEDS (*Continued*)—

eradication may be assisted by hand pulling after rain, and by close depasturing with sheep in spring and early summer.

Umbelliferæ.

Wild Carrot (*Daucus carota* L.) is often very troublesome on poor dry pastures, and in leys, particularly on calcareous soils. It is annual or biennial, and seeding may be prevented by cutting or spudding, and general improvement is called for. (See Seeds and Weeds Act, 1920.)

Urticaceæ.

The Nettle (*Urtica dioica* L.) may be very troublesome in grass land of poor type. Frequent cutting, a dose of 5 cwts. of salt per acre on the affected areas, scarifying, liming, and manurial treatment, 1 lb. of wild white clover seed per acre, and close depasturing, should soon effect an improvement.

Polygonaceæ.

Sheep's Sorrel (*Rumex acetosella* L.) and *Common Sorrel* (*R. acetosa* L.) are sometimes very plentiful on poor grass land. Both may be reduced by methods adopted to improve the general herbage, and particularly by an application of lime.

Liliaceæ.

The Wild Onion (*Allium vineale* L.) occurs very extensively in grass land, from which it is as difficult to eradicate it as from arable land. Moreover, it is very injurious from the point of view of milk production, as it so badly taints the milk of cows that consume it as to render the milk unfit for human consumption. It may likewise taint the meat of stock so badly as to render their transfer for a period before slaughter to land free from the weed essential. On grass land persistent cutting and hand pulling from spring until autumn, together with close depasturing with store stock, and improvement of the herbage to crowd out the weed, should be successful in reducing it.

Juncaceæ.

Rushes (*Juncus* spp.), *Cotton Grasses* (*Eriophorum* spp.), and *Sedges* (*Carex* spp.) all occur extensively on damp land, such as water-meadows and low-lying damp meadows. All may be combated by drainage, liming, cutting and general improvement of the herbage.

Gramineæ.

Weed Grasses are fairly plentiful. *Floating Foxtail* (*Alopecurus geniculatus* L.), and *Tufted Hair Grass* (*Aira cæspitosa* L.) are liable to be very troublesome in damp meadows. Draining, liming, and manuring are indicated as the best means of reducing these grasses.

Bent Grasses (*Agrostis* spp.), *Wavy Hair Grass* (*Aira flexuosa* L.) *Yorkshire Fog* (*Holcus lanatus* L.), *Quaking Grass* (*Briza media* L.), and *Brome Grasses* (*Bromus* spp.) are all likely to be greatly reduced when a general improvement of grass land is taken in hand. Yorkshire fog and the brome grasses may also be dealt with by mowing early for hay before seeding takes place, both being either annual or biennial.

Polypodiaceæ.

Bracken (*Pteris aquilina* L.) frequently causes great trouble by encroaching upon dry upland pastures and rough grazings—and even

WEEDS (*Continued*)—

sometimes invading better pastures. It can be dealt with by cutting two or three times a year between mid-June and September for two or three years. The first cutting may be when the fronds are about eight or nine weeks old, before the stems are hard. Cutting may be most quickly done on suitable land with the aid of an old mowing machine. Where the ground is very rough a hook, scythe, or wire switch may be most successful, while the use of heavy chain harrows is likely to be effective when the bracken is fairly brittle. The presence of bracken in quantity is regarded as a sure sign of lime deficiency, and an application of lime is likely to lead to great improvement, especially when accompanied by cutting as suggested. The use of fertilizers, especially phosphates and potash, may be expected at this stage to effect much change for the better: the more the grazing is improved the more stock will graze upon it and lead to reduction of the bracken. Salting (2 to 4 cwts. per acre) seems to have a similar effect in attracting stock, the result being a reduction of the bracken by both consumption and destruction of the fronds by treading.

Spraying with a 5 per cent. solution of sulphuric acid (sp. gr. 1·72), when the fronds are almost unfolded, has also been found effective.

Equisetaceæ.

Horsetails (*Equisetum* spp.) occur widely on grass land. They are likely to be reduced by any method which will lead to an improvement in the general character of the herbage.

REFERENCES.—Winifred E. Brenchley, "Weeds of Farm Land," 1920. Ministry of Agriculture and Fisheries, "Weeds of Arable Land," H. C. Long, 1929. R. G. Stapledon and J. A. Hanley, "Grass-land: Its Management and Improvement," 1927. H. C. L.

WEIGHING MACHINES AND WEIGHBRIDGES—These are used for heavy weights; for smaller instruments see Balance. The simplest instrument of this kind is the ordinary barn-yard scale for weighing sacks, etc. In a balance the pans are kept hanging vertically by gravity, but when heavy weights are in question a small swing tends to persist for a long time. In the barn-yard scale the pans are stabilized by fixing them rigidly to a hinged framework which is itself swung from the knife edges. For heavier weights the weighbridge is used. This is almost invariably arranged on what is called the lever system. Fig. 39 shows the parts of such a weighbridge diagrammatically. The weighbridge table T rests on knife edges x, y, fixed to two levers F_2z F_1a respectively. These levers are suspended from the frame by stirrups, to which they are hinged at F_2 and F_1. At a is a connecting rod which passes to a third lever, bc, supported on a knife edge at F_3, the knife edge being fixed to the frame. Thus, the points F_1, F_2, and F_3 are immovable. When a weight is placed anywhere on T the weight will be carried by x and y together, but not in equal proportions, unless the weight is placed centrally on T. If it is placed nearer to y, this knife edge will carry more of the weight than x, but the pressure on y + the pressure on x will always be equal to the weight on T. Now in the sketch as drawn, $F_1y = \frac{1}{5}F_1z$, so that the force at z due to the pressure

WEIGHING MACHINES AND WEIGHBRIDGES (*Continued*)—

on y will be $\frac{1}{5}$ of the pressure on y. Similarly, since $F_2x = \frac{1}{5}F_2z$, the force at z due to the pressure on x will be $\frac{1}{5}$ of the pressure on x. Hence the total force at z will be the sum of these, *i.e.*, $\frac{1}{5}$ (pressure on x + pressure on y) $= \frac{1}{5}$ weight on T. Thus, wherever the weight may be placed on T, the force at z would be $\frac{1}{5}$ of it, and so the weighbridge will work correctly wherever the weight is placed on the table. To continue, $F_1z = \frac{1}{3}F_1a$; therefore force at $a = \frac{1}{3}$ force at $z = \frac{1}{3}\cdot\frac{1}{5}$ weight on T, and this is transferred unchanged to b. $bF_3 = \frac{1}{12}F_3c$; therefore force (upward) at $c = \frac{1}{12}$ force at $b = \frac{1}{12}\cdot\frac{1}{3}\cdot\frac{1}{5}$ weight at T. Thus, 1 lb. at the end of the lever at c will support 180 lbs. on the weighbridge at T.

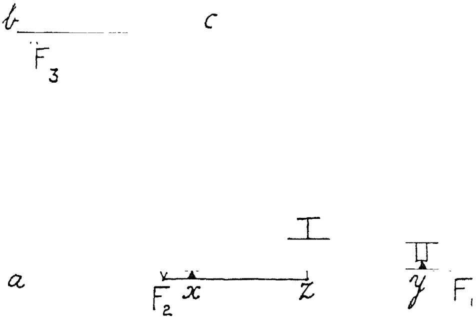

FIG. 39.—WEIGHING MACHINE AND WEIGHBRIDGE.

Automatic grain weighers are in essence merely balances in which the kinetic energy of the material falling from the hopper is used to operate the feed shut off and emptying mechanisms. Usually, the shut off is carried out in two stages, the flow from the hopper being considerably reduced as the material in the pan is nearing the required weight so as to reduce error. No further useful description of these contrivances can be given in the space here available; a short explanation of the action of the "Avery" machine will be found in E. A. Griffiths' "Engineering Instruments and Meters" (Routledge, London, 1920, pp. 265-269).

WEST INDIES, Agriculture of—See Agriculture.

WHEAT—Introduction—Wheat has been cultivated over the greater part of the Old World from prehistoric times, and now occurs from about 67° N. latitude to subtropical regions. It is not surprising, therefore, that many widely different types can be found; but all these are considered by botanists to form a single genus, *Triticum*, which consists of three well-defined groups of species. The first group, which contains only the wild grass *T. ægilopoides* and the cultivated *T. monococcum*, grown as a forage crop in certain mountainous districts of Europe, is of little importance. The second group contains several species whose cultivation centres in the Mediterranean region; the most important being *T. durum*, macaroni wheat, and *T. turgidum*, of which our English "Rivet" or "Cone" wheat is an example. To this group also belongs *T. dicoccum*, now only cultivated in scattered patches by primitive peoples, but probably the most generally cultivated wheat in prehistoric times. The third group, in addition to some relatively unimportant forms, contains *T. vulgare*, common or bread wheat, the most important species of the genus, and the only

WHEAT (*Continued*)—

one used extensively for making bread in civilized countries to-day. The greatest number of forms of this species are found in Afghanistan and neighbouring countries, which are probably its original home. From this centre it has spread widely over the Old World, and in modern times has been introduced to North and South America, Australasia, and South Africa.

Most of the world's wheats have a short growing period, and are either spring sown or, as in North Africa, are sown in autumn and ripen in April or May before the advent of hot weather; but in Great Britain nearly all have a long growing period of nine or ten months, and all the forms are similar in type. It is apparent from its almost world-wide distribution that wheat can be grown under the most diverse conditions, but it succeeds best with a moderate rainfall and a warm, dry ripening period. Its cultivation in Britain consequently centres in the eastern counties and east midlands of England, and diminishes as we leave this centre (see Fig. 40). Similarly, in the dry eastern counties the acreage is greater in Essex and Suffolk than in Norfolk, with its predominantly light soils. It is only in recent times, however, that the area of the crop has been restricted in this way; and in 1875 Devon, which now grows little wheat, grew more than most of the eastern counties do now, while in Ireland the area has declined from 743,871 acres in 1847 to 31,263 acres in 1930. The total area under wheat in England and Wales fell from about 3 million acres in 1878 to about 1·4 millions in 1904. After this there was a rise, especially during the war, followed by a fresh fall to about 1·4 million acres in 1928.

According to the "Agricultural Output of England and Wales, 1925," and the corresponding records for Scotland and for Northern Ireland, the area devoted to wheat in that year amounted to 1,552,639 acres. In 1930 there were 1,403,523 acres, and the acreage distribution in the two years was as follows:

	1925.	1930.
England Wales	1,500,000	1,346,000
Scotland	49,000	53,000
Northern Ireland	3,639	4,523

The total consumption in the United Kingdom is about 6 or 7 million tons annually, and in recent years about 80 per cent. of this quantity has been imported.

Varieties—There is, perhaps, too little exact knowledge concerning the adaptation of varieties to special localities; although the conditions under which wheat is grown are so similar nowadays that very marked adaptations would not be expected. Wilhelmina is probably the highest yielding variety under average conditions, but it is outyielded by Little Joss on the lighter soils and on land in poor condition. The latter variety is also widely grown in the Fens. The Swedish variety Iron III., and Weibull's Standard, possibly come next to Wilhelmina in yield, and have proved valuable on heavy soils, but their cultivation is diminishing. Yeoman succeeds well on fertile soils, and is the predominant variety in parts of Lincolnshire. It is suitable

WHEAT (*Continued*)—
for intensive cultivation on account of its rust resistance and good straw. Square Head's Master, and the closely similar Standard Red, will ensure a return under low standards of cultivation and give consistent results from year to year; their cultivation has spread considerably during the last few years of depression, but in most localities and under normal conditions they are likely to be definitely out-yielded by the more modern varieties mentioned above (*J.N.I.A.B.*, Vol. II., p. 89).

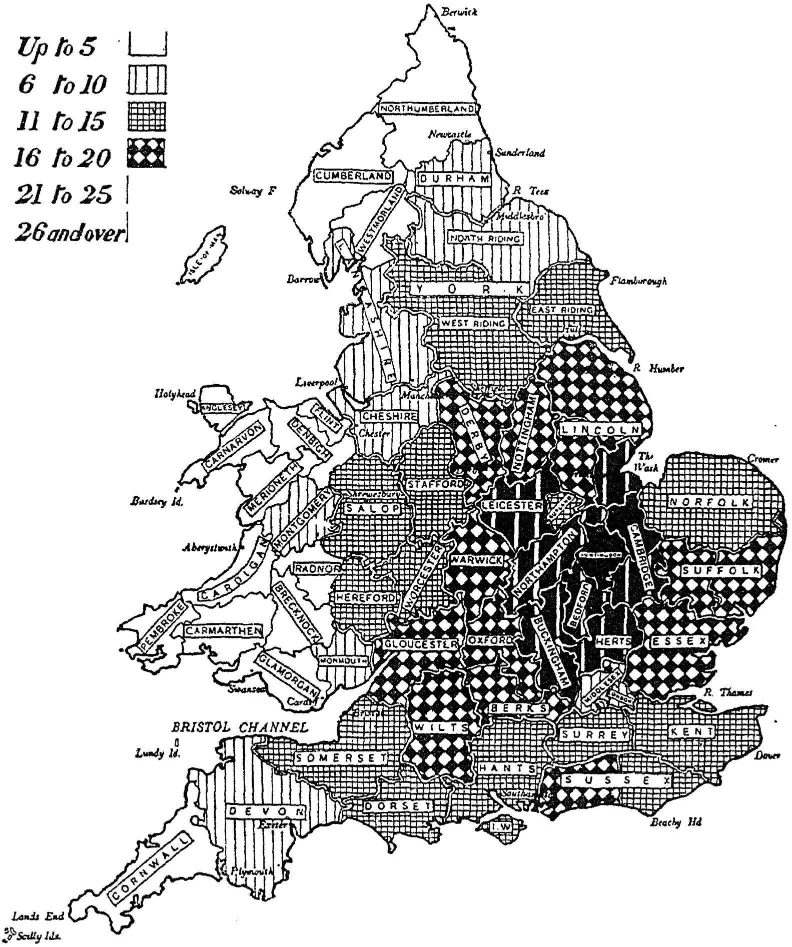

FIG. 40.—SHOWING THE NUMBER OF ACRES OF WHEAT PER 100 ACRES OF ARABLE LAND IN 1925.
(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

WHEAT (*Continued*)—

When Yeoman was tested against Square Head's Master in an intensive manuring trial, the latter variety was badly lodged; but the Yeoman not only stood well, but gave a much greater increase in yield for the manure supplied (*loc. cit.*, ii., p. 100, 1929). Rivet or Cone wheat, a mixture of closely similar strains of *T. turgidum*, is grown in patches on cold and wet clay soils, conditions which it tolerates better than other varieties; the grain is of poor quality and fetches a low price, but under suitable conditions the yield obtained may be higher than that of any other variety. Two spring varieties, Red Marvel and April Bearded, are occasionally grown.

In the climate of the eastern counties and east Midlands a dry September and October—that is to say, dry weather before and after seeding—is more important for a good crop than the rainfall or temperature at any other period of the year. Apart from this period a warm, dry winter and a cool spring seem to be beneficial (Hooker, "Correlation of the Weather and Crops," *J. Roy. Stat. Soc.*, vol. lxx., part i., 1907).

Position in Rotation—Wheat is sown most usually after a clover ley or some leguminous crop such as beans; but on one of its principal areas, the heavy land of the eastern counties, it frequently succeeds some description of fallow. In some parts—in Ireland, for example—it may follow roots carted off; and, finally, it may succeed another wheat crop. In general, therefore, it is grown when the soil is in its most fertile condition; and it is clearly well suited to this position, since it stands better than barley or oats, and the quality of the grain may actually be improved by an abundance of nitrogen in the soil.

Cultivation, etc.—It is a deep-rooted plant, and the tillage operations should aim at producing a deep layer of well-worked soil for the roots to develop in. Too fine a surface to the seed-bed is undesirable, particularly on a soil liable to run together; and clods, if not large enough to interfere with drilling, are an advantage in protecting young plants against cold winds. Both free drainage and a firm seed-bed are necessary.

Drilling is carried out at distances of from 6 to 8, 9, or 10 ins.; horse hoeing being carried out at the wider distances when necessary. From 2 to 3½ bushels per acre of seed are sown, 2½ bushels being usual, and to ensure the maximum crop a regular distribution of seed in the drill row is most important. (See Seed, Spacing of.) Harrowing and rolling one or more times, both along and across the drill rows, promote tillering and check wireworm and leather jacket; while sometimes the crop is also horse hoed and may be hand weeded. These operations complete the cultivation needed up to harvesting.

Manuring—Mention has already been made of the two features which allow wheat to be grown on richer soils than barley or oats, but if it is grown after a leguminous crop, a fallow, or a root crop, the application of artificial manures is usually unnecessary. On the other hand, should it succeed another straw crop or be grown on impoverished soil, artificial manures are usually added. It is clear that no simple rules

WHEAT (*Continued*)—

for manuring can be formulated, judgment of the fertility of the particular field being the first essential; but it is probable that in many cases the amount of fertilizers applied could profitably be increased. Fear of lodging is the restraining feature, and though the excellent standing of some of the modern varieties may not be fully utilized, the need for new varieties with still stiffer straws is evident.

Much the largest increase in grain and straw is obtained from nitrogenous manures; but the addition of mineral manures as well, *i.e.*, of phosphates and potash, may be important, especially when intensive manuring is adopted, since a well-balanced manure makes lodging less likely and reduces the loss arising from fungous diseases, while excessive nitrogen renders the crop very liable to both these dangers. The mineral manures are also beneficial in other directions. Phosphates, for instance, encourage root development and hasten ripening, a valuable property on cold soils and in seasons of heavy rainfall; while potash is useful in dry seasons by preventing premature ripening, with its attendant results of small and shrivelled grain.

Phosphates (which may be given in the form of superphosphate, or of basic slag on land deficient in lime) and potash are usually applied shortly before drilling; and this should generally be the best practice, since the losses in drainage are small, and the encouragement given to an early and full development of the roots helps the plant to obtain a good start. But the position is not so clear in the case of the nitrogenous manures, which are easily washed out of the soil and lost; for a great part may be wasted if they are applied in autumn, when the soil is wet and the slowly growing plants are not able to utilize them quickly enough. And although this difficulty may be circumvented by applying them in spring, when rapid growth begins, an earlier application has the advantage of giving the plant a good start and promoting early tillering; the latter feature is important, since it is only the early tillers that make an effective contribution to the final yield. The subject should repay experiment; but the usual custom is either to apply a portion in the autumn, and the balance in spring, or to give the whole in the spring.

Nitrate of soda appears to have a slightly greater effect on yield than sulphate of ammonia, but here again the rainfall is a qualifying factor. When this is small, the sulphate of ammonia does not pass the upper layers of the soil, while the more readily available nitrate of soda permeates the lower levels more easily and therefore comes within reach of the greater mass of roots. On the other hand, with more abundant rainfall much of the nitrate of soda may be lost, while the sulphate of ammonia is merely washed to within range of the roots. Nitrate of soda, too, may have a bad effect on the texture of heavy soils if applied continuously.

The usual mixture recommended for wheat is:

1 to 1½ cwts. of sulphate of ammonia.
3 cwts. of superphosphate.
2 to 3 cwts. of kainit or 1 cwt. of sulphate of potash.

WHEAT (*Continued*)—

As already explained, however, the mixture must be subject to considerable alteration to accord with what is known concerning the richness of the soil in the several constituents. (See A. D. Hall, "An Account of the Rothamsted Experiments," John Murray, London, 1905; also article, Manuring, Principles of.)

Utilization of the Crop—Almost the entire English crop is used either for (1) bread making, (2) flours other than bread flour, (3) biscuit making, or (4) poultry feeding. The proportion used for poultry has increased considerably in recent years and may increase still further; but the general position may be illustrated sufficiently well by the estimate given in 1928 (" Report on the Marketing of Wheat, Barley, and Oats in England and Wales," *Min. Agric. and Fisheries*, Econ. Ser., No. 18, 1928) that about 30 per cent. of the crop is used for bread making, and that the remainder is divided about equally between the other three. The type of wheat required for these different purposes is definitely different. From the bread-making standpoint wheats vary in quality between those that are " strong " or " hard," and give a large loaf of light texture, and those that are " weak " or " soft " and give a small, heavy loaf. Flour for the ordinary English loaf is made by blending these soft and hard forms; and since the world produces more soft than hard wheats, the latter command a higher price. All English wheats, except Yeoman, are definitely soft: Yeoman is fairly hard, and bread can be baked from Yeoman flour alone with no admixture of harder varieties. For biscuit making, however, soft wheats are required; and English wheat is generally used, not only because it is weak, but because of its good flavour. Its suitability for this latter purpose does not, of course, help the price it fetches, since not all the English wheat can be used for biscuit making, and the surplus is of low value for bread making. For poultry feeding, quality in the above sense seems to have no importance; any variety with large grains is suitable, but white wheats are often preferred to red (E. T. Halnan, " Digestibility Trials with Poultry," *J. Agric. Sci.*, xviii., 421-431, 1928). On the whole, we may estimate that, at present, some half of the English crop is put to uses for which strong varieties are desired.

Conditions influencing Present-day Prices—It is remarkable that from 1646 to the present day the price of wheat has changed little in its general level over a period of years; though it has, of course, always been subject to violent fluctuation, since the supply varies from season to season and the demand is almost unaffected by price movements unless these are very large. During the whole of this time, if we except the periods of the Napoleonic wars and the recent World War. it has only rarely been higher than 70s. a quarter or lower than 25s., and these extremes were reached as often in the past as in our own day, Nowadays, the price of English wheat is determined primarily by the world price—that is to say, by the relation between the world's exportable surplus and the demand of the importing countries. The world's present wheat area may be estimated very roughly at about

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280 million acres. The yield varies enormously: in 1923-27 the average yield per acre in Holland was estimated at 21, in Great Britain and Northern Ireland at 17½, and in Australia at about 6¾ cwts. per acre. Most of the world's production is used where it is grown; and the exportable surplus, which averaged about 17 million tons in 1923-27 and came chiefly from the British Empire and the United States, forms only a comparatively small proportion, perhaps one-seventh, of the total world production. About 33 per cent. of this surplus—that is, about 6 million tons—is taken by the United Kingdom, which, as we have seen, imports nearly 80 per cent. of its total supplies, and in this respect is unique; the remainder being taken by a few European countries, notably Belgium, Holland, Italy, and sometimes France. To appreciate the world position, therefore, it must be realized that the greater part of the crop is already consumed where it is grown; and that the relatively small surplus may at any time be increased by extension of the acreage in countries whose resources are not yet completely exploited. It may be true that in proportion to the whole output the world's wheat production cannot be very greatly extended; but a relatively great increase, as far as the exportable surplus is concerned, is possible, and does occur, as soon as the price rises to a level considered attractive in exporting countries such as Canada and the Argentine. The general position is, of course, greatly complicated by a number of features, such as the uncertain position in the U.S.S.R., where the total acreage is very great and there is no doubt that the yield could be increased appreciably by the use of better varieties and improved methods of cultivation. Again, an increase in the standard of living in certain countries, *e.g.*, Japan, has meant in the present century an increasing consumption of wheat; but, on the other hand, in the United States the consumption of wheat per head has decreased as a result of an increase in the consumption of other foods, such as fruit and dairy products.

English wheat normally fetches a markedly lower price than many imported forms, partly because the climate causes it to have a higher water content (about 14 to 22 per cent. as against 10 to 15 per cent. for that from Canada and the United States), and partly because all the varieties grown until Yeoman was introduced are poor in quality from the bread-making standpoint. It was expected that Yeoman would command a markedly higher price than other English varieties, and sometimes it does, but the question depends a good deal on local conditions. Thus, if the crop is required locally for biscuit making, weak varieties are needed, and Yeoman may actually be at a discount; and in other districts most of the crop may go for poultry feeding (*e.g.*, about 80 to 90 per cent. in Northumberland and only 15 per cent. in the eastern counties; see Marketing Report quoted above), for which purpose "strength" is a matter of indifference. An increased cultivation of strong wheat, where there is a market for it, ought to raise the price of all English forms, whatever their quality, since the weak forms would no longer form a surplus. Conversely, if strong forms are not grown, the price will probably fall still further below

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the world price, since the tendency for all bread flour to be milled at the ports would increase, and the cost of carriage to the port would fall on the surplus English weak wheat.

Improvement of the Crop—The fact that the crop has long been cultivated in England, probably for some thousands of years, has automatically ensured that the surviving types are those best suited to the climate; and no doubt the natural process has been helped at times by conscious selection by man. Following the improved agricultural methods introduced in the eighteenth century, greater attention was probably paid to crop varieties; and in 1836 the modern principle of selecting the best pure line (see Mendelism) had been adopted by Le Couteur, of Jersey (J. Le Couteur, " On the Varieties, Properties, and Classification of Wheat," 2nd edit., London, 1872). His efforts, and the work of those who came after him, probably effected a definite improvement in the varieties in general cultivation; and there is no doubt that, as far as yield is concerned, a high standard had been reached by the end of the century, while subsequent improvement has been only slight. This is shown most clearly by the fact that Square Head's Master, which was introduced into cultivation about fifty years ago, is outyielded by only one or two of the modern varieties; while its general reliability under a wide range of conditions has actually increased its cultivation in recent years, and it is now probably grown more widely than any other variety. There is certainly no doubt that although a constant stream of new varieties appears, nearly all these are either definitely inferior to those already in cultivation or are closely similar to them in all respects; and, in actual fact, very few survive for many years. It may well be doubted, indeed, whether it will be possible by present methods to produce new varieties that outyield the old by more than some few per cent. Much has been done by the application of Mendelian methods to breeding (see Mendelism), but experience shows that the greatest value of this method has been either in remedying some definite defect, such as lack of baking quality in our own wheats or susceptibility to attacks of Rust, or in producing varieties suitable for cultivation in new countries or to meet new needs. But although the chance of producing varieties better adapted to present conditions may not be great, there is probably scope for improvement in meeting changed conditions, such as the increased use of wheat for poultry feeding and the abundance of cheap fertilizers. It should be possible to produce a series of varieties that would well repay, and would stand up under, the use of much heavier dressings of artificial manures than are at present applied; and since Rivet wheat is apparently suitable for poultry feeding (E. T. Halnan, *loc. cit.*), the cultivation of this excellent type might be greatly extended by producing a series of forms of it adapted to growth under a wider range of conditions.

At present, however, there is no doubt that full advantage is not taken of the excellence of existing varieties. A yield of 32 bushels per acre may be regarded as typical for wheat in England; but 96 bushels

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per acre of Yeoman wheat were grown in 1918 at Wye, in Kent, on a deep loam overlying brick earth. While testifying to the excellence of modern wheats, such a result suggests not merely the importance of producing stiff-strawed varieties, but that a considerable improvement in yield could be effected by the general adoption of improved methods of cultivation and manuring.

For diseases and insect pests of this crop see articles immediately following; for composition, feeding value, and manurial value see Feeding Stuffs, and Poultry, Nutrition; other articles to which reference should be made are: Grain, Commercial Standards of; Agriculture, Australia; *idem.*, Canada; *idem.*, British Isles, Crop and Other Statistics of; and Seed, Transmission of Plant Diseases by.

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A. E. W.

WHEAT, QUALITY IN—The miller's requirements in the matter of wheat quality are quite other than those which have usually contented the grower of wheat in this country, except in so far perhaps as cleanliness and good appearance of the grain are concerned. The miller is not directly concerned with the yield per acre of any given type of wheat. He desires that the grain shall be plump, uniform (both as regards the type of grain present and size of kernel), free from damage either mechanical or biological (*e.g.*, by "heating" or sprouting), of high weight per bushel and of good milling quality, of low moisture content, and, ordinarily, of high protein content. The protein should be of satisfactory baking quality. For bread-making flours, a red type of grain is generally preferred.

Milling quality is not only a matter of yield of flour, but of the ease and satisfaction with which the endosperm can be separated from the bran coats and subsequently reduced to flour. It has been said that "milling some types of wheat is like shelling a nut, whereas with others it is more like peeling an orange." High milling quality in this sense is naturally desired by the miller, not only on account of the greater ease and freedom from trouble and anxiety, lowered power consumption, and so on, involved in the processes, but because it implies a flour of better marketable value. Such a flour would be of better physical properties, being freer from specks and bran snips, paler in colour and of better "bloom," superior in "feel" and "liveliness," and lower in ash content.

Most of the factors in milling quality are interconnected. For example, the bushel weight (which is a criterion less used commercially in connexion with home-grown wheat than with imported wheat) (see Grain, Commercial Standards of) is of importance because it is a guide to milling yield or flour extraction (*i.e.*, the amount of endosperm, expressed as a percentage of the wheat fed to the mill, obtained in the form of flour). It depends in part on the plumpness of the

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grain, but is equally dependent on the intrinsic endosperm content of the grain (*i.e.*, whether the bran coat is relatively thick or thin), which is affected by variety.

High bushel weight, again, implies low moisture content. Now moisture content is a factor of obvious direct concern to seller and buyer alike, and it must always be a basis of price. Good, dry wheat deserves a premium out of direct proportion to the actual dry matter content present, for the simple reason that drying wheat is an expensive process. The application of this will be realized when it is pointed out that there are fairly close limits to the possible range of moisture content for the satisfactory milling of a given type of wheat, and that English wheat on the market frequently exceeds these limits. Moreover, it is almost always the practice to wash the wheat before milling, in the interests of flour colour. Apart from this, the miller naturally prefers not to buy water, and it must be remembered that home-grown wheat, whose moisture content may vary from, say, 14 to 22 per cent., is in competition with imported types of moisture content of only 8 to 15 per cent. (Moisture figures depend to some extent on the method of determination. The figures given above correspond to four hours' heating of a coarsely ground sample in an electric air oven at 120° C., and run about 2 per cent. higher than "water oven" figures often quoted.) Not unnaturally, much variation in the moisture content of English wheat occurs during any one crop year, and it is not unusual for a farmer who manages to get his crop threshed early to market wheat drier by 4 per cent. than a later competitor.

Damage or unsoundness in the grain, due to "heating" or to incipient germination or sprouting, in turn due to past or present excessive moisture content of the grain, is feared by the miller partly because of its disturbance of the relative physical characters of bran and endosperm on which satisfactory milling depends (damage tends to make the bran brittle instead of tough), but mainly because of its far-reaching deleterious influence on baking quality.

Turning now to baking quality or "strength," this is dependent for all practical purposes only on the protein content of the endosperm which constitutes the gluten. Baking quality is affected both by quantity and quality of gluten, and of these two factors, quality is the more important. It reflects the physico-chemical properties of the gel structure which the gluten forms with water.

A flour of high protein quality is differentiated in the bakehouse from one which is poor in this respect to an extent which is difficult to communicate adequately in words to those unfamiliar with baking practice. In the first place, the former absorbs and holds more water when the dough is made, a difference which persists throughout the baking process to the finished bread. In other words, it yields more loaves per sack. It gives a dough which has superior handling properties in every respect. This is an aspect of "strength" which is frequently not sufficiently stressed. A strong flour gives a dough which is of better body, tougher, more extensible, and more stable than a weak one. Translated into everyday terms, the strong dough is more

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satisfactory to handle; it is easier to work and requires less " nursing "; it does not tend to flow about the table like so much porridge. The difference is of equal importance whether hand or machine baking methods are employed.

The " strong " flour has a longer fermentation period and greater fermentation tolerance. Each flour, using a given proportion of yeast and a given temperature, requires a certain time of fermentation to " mellow " the dough properly, and to give the best loaf. This is its fermentation period. This is sharply defined with some flours, whereas with others, whose tolerance is greater, a certain time difference either way has little effect on either the " feel " of the dough or the quality of the resulting bread. A flour which is more " foolproof," which requires less care and attention during fermentation, and is less likely to go wrong in the event of accident or inadvertence, is obviously worth more to the baker.

The " strong " flour gives the larger, better risen loaf, because the gluten network is better able to hold the gas liberated during the final stage of fermentation, and expanded during the first few minutes in the oven. The outside appearance is altogether more handsome and the loaf more saleable in consequence. Its crumb is much better developed: it is softer, is more elastic, and has better powers of recovery if " thumbed," and its grain or vesiculation of the crumb is more attractive; in short, it is more appetizing and far more easily digestible.

The English farmer's reaction to the flood of " strong " wheat which entered the English market after the opening up of the American prairies was to concentrate on yield per acre at the expense of quality. Varieties like Square Head's Master found favour in place of Talavera, Lammas, Rough Chaff, and so on, which had served their generation well, both from the farmers', millers', and bakers' points of view.

From a milling point of view, Square Head's Master is plump, uniform, and larger-berried than the typically strong Manitoba wheat, but its bran coat is thicker and more difficult to free completely from adhering endosperm (flour). It may give as high a yield of flour as Manitoba, but the milling operations are on the whole more difficult. Although the Manitoba endosperm is harder, its flour is " livelier," and is more satisfactory to handle and sift than the English, which often gives trouble in sieving machines and rolls alike on account of its softness and " stickiness." The Manitoba flour is " lively " and granular to the feel, whereas the English is soft and impalpable, but if well-milled the English perhaps has the advantage of a fine, almost pure white colour.

Square Head's Master is a typically " weak " and Manitoba a " strong " wheat. The flour from the former may absorb water at the rate of 14 to 15 gallons per sack (of 280 lbs.); the latter should absorb not less than 16 gallons. The former gives a dough of inferior handling properties: tender, sticky, of poor extensibility and stability (*i.e.*, it has a tendency to flow). The Manitoba dough is tough, extensible, and of excellent stability. While the English dough in

WHEAT (*Continued*)—

certain baking processes might require three hours' total fermentation, and forty-five minutes under or over would ruin the bread, the Manitoba might give first-class bread at any time from four to six or more hours.

The differences in bread quality have been sufficiently indicated above.

The degeneration of English wheat alluded to above was complete by about 1890. It should be pointed out, too, that standards and requirements in the flour trade had changed by then. The home-baking and brewers' barm of the old days had given place to trade baking and distillers' yeast; imported flour of superfine quality from Hungary and subsequently from North America literally opened the nation's eyes and imposed a new and higher standard of bread quality; the revolution in milling methods meant better results with foreign hard wheats than had been possible with home-grown grain under the old system. A further important factor was the high cost of transport in this country as compared with ocean transport and that of the great wheat-growing countries. As a result of this complex set of circumstances arose the great merchant mills at the ports. In such circumstances the small country miller was placed at serious disadvantage in competition with the dock-side mills of the ports, and he has been slowly but steadily disappearing. With him goes the farmer's hope of profitably marketing home-grown wheat for bread-making. The fate of the English wheat grower is closely bound up with that of the country miller. The magnitude of the change is indicated by the following approximate figures: it has been estimated that in the middle of the nineteenth century, there were about 10,000 small mills scattered all over the country, each dealing mainly with the wheat grown in its own neighbourhood. At present more than 90 per cent. of the total wheat milled in this country is milled by 300 concerns, and approximately half the wheat milled is milled in the three port areas of London, Hull, and Liverpool (with Birkenhead).

It is clear that the future of English wheat-growing depends on the production of native wheat sufficiently high in quality to enable the country miller to produce a reasonably satisfactory flour without the aid of imported produce—wheat that, as of old, may be milled and consumed in the district where it is grown.

Much work has been done with this object in view by the Home Grown Wheat Committee of the National Association of British and Irish Millers. This committee was constituted in 1901 under the chairmanship of A. E. (now Sir Albert) Humphries, and subsequently collaborated closely with Professor (now Sir Rowland) Biffen of the Cambridge School of Agriculture. In the early years a study was made of the influences of certain factors in cultivation on quality. Manuring, though essential to satisfactory yield per acre, has proved most disappointing as far as its influence on quality is concerned. Nitrogenous manuring in ordinary dosages may be said to have no effect upon either quantity or quality of protein in the grain, whilst heavy dosages applied to the same soil year after year, though increasing the nitrogen content of wheat grown on the site, are erratic

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in their effect on baking quality. The phenomenon is complex, and appears to be connected with climatic conditions. It can be said, however, that in the present state of our knowledge the economic improvement of wheat quality in this country by means of manurial treatment does not present a very promising line of development.

It is well known that the world's "strong" wheats are grown under climatic conditions best described as "continental," especially involving a warm, dry, ripening period. Attempts to raise the quality of English varieties by growing them under such conditions, however, have failed. Square Head's Master wheat from England grown in the best districts of Hungary turned out no stronger than normal. Again, the effect of an exceptionally warm, dry, English summer cannot be said to improve the average baking quality of home-grown wheat. Thus, the English summer of 1927 was such as would be deemed unfavourable to good quality in wheat, whilst the weather during the summer and early autumn of 1929 was excellent. Yet of the wheats harvested at the various stations of the National Institute of Agricultural Botany, and examined by the Home-Grown Wheat Committee, those of the 1929 crop were of poor baking quality and inferior to those of 1927. Some of the world's strongest wheats are early ripeners, partly owing to varietal differences and partly because they are grown in northern latitudes where active growth is carried on over a lengthy period of hours each day, but it has been shown definitely that the strength of English wheat is increased neither by spring sowing nor by unusually rapid maturation. Nor is there any hope of increasing the bread-making value of English wheat by varying the stage of ripeness at which the grain is cut.

Some very "weak" wheats are grown in the world's strong wheat districts—a fact which tends to heighten the importance of *variety* in the quest for strength. Yet with one exception strong wheats produced from abroad and grown in England have failed miserably both in yield and agricultural quality generally, and in "strength." The number of varieties which have been tested in this way is considerable, and it must suffice to direct attention to the reports of the Home-Grown Wheat Committee from 1901 on.

At this point we may turn to the work on breeding new varieties of wheats for English cultivation which has been carried out by the Home-Grown Wheat Committee in association with Sir Rowland Biffen. It was early found that the above-mentioned exception to the rule that strong foreign wheats became weaker when grown in England was Red Fife, a Canadian "strong" wheat originally obtained from Galicia, via England. It was introduced to England in 1892 under the name of Cook's Wonder. Red Fife has suffered no deterioration in strength even after being grown continuously (*i.e.*, grown from its own seed year after year) in this country for over a quarter of a century. At the same time, it has proved commercially unsuccessful owing to unreliability of yielding power, the delicate nature of the plant, its poor straw, susceptibility to rust, and so on.

The purpose underlying the work of the Home-Grown Wheat

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Committee was to produce a wheat having the yielding capacity and satisfactory agricultural features of a strain like Square Head's Master, together with the strength of Red Fife. The progress made depended on the demonstration that characters of economic significance—early ripening, resistance to disease, baking quality, cropping power—were Mendelian units in the same sense as botanical characteristics such as presence or absence of awns. The course of the work was naturally very extensive and can only be appreciated by study of the numerous Reports issued from time to time by the Home-Grown Wheat Committee. The work was early rewarded by the breeding of Little Joss, which combined the good cropping power of Square Head's Master with the rust-resistance of Ghirka, its parents.

The greater achievement—the linking up of cropping power with the baking quality of Red Fife—was slower in coming. The breeding of Yeoman from Red Fife and Browick, however, was a big step towards this ideal. Grown in suitable parts of the country, Yeoman yields satisfactorily, has good straw which stands well, and is rust-resistant. It behaves in the mill like a strong foreign wheat and quite unlike ordinary English varieties: its endosperm particles are lively and easy to sift, and its flour granular and pleasing—all in marked contradistinction to the softness and stickiness typical of English wheat. Though it cannot be said to have higher protein content than other English wheats, its gluten is distinctly better in quality.

The same remarks apply to Yeoman II, which was a later selection from the progeny of the same parents which gave Yeoman. Yeoman II, however, is a harder wheat still, and has distinctly better gluten quality than Yeoman. The flour from Yeoman II has higher water absorption than ordinary English, giving a dough which, though not tough and "rubbery" to anything like the extent characteristic of strong foreign varieties, is nevertheless of quite satisfactory handling properties, and has appreciably greater fermentation time and tolerance than ordinary English wheats. The bread, again, is very different: though distinct from the product of, say, No. 1 Manitoba wheat, it is not greatly inferior to that baked from mixtures of wheats which constitute a miller's ordinary grists. That is to say, flour milled from Yeoman II wheat alone will give satisfactory bread, suitable for sale, when baked in tins. Like Yeoman, its weakest feature is dough stability: the dough tends to flatten or spread during fermentation, a defect which it shares with ordinary English varieties, although to a less extent, in consequence of which it does not as a rule make satisfactory cottage loaves.

Yeoman and Yeoman II, between them, now share with Square Head's Master the distinction of being the most widely grown of English wheat varieties. The present need is for strains equal in strength to Yeoman II. suitable for growing in localities where this variety is unsatisfactory from the cropping point of view.

Of the other varieties in cultivation, with the exception of Rivet, there is not sufficient evidence to show that any one has marked superiority over any other: all appear comparable with Square Head's

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Master. Iron III, in spite of its poor reputation among millers and its unusually low gluten content, is not as a rule inferior to Square Head's Master. Although millers prefer red wheats, these do not appear to be in any way superior to white wheats such as Victor or Wilhelmina. In fact the Home Grown Wheat Committee have stated (1928) that "the differences in quality for bread-making purposes are not sufficient to affect the farmer's choice when he is considering for commercial purposes whether he will sow Square Head's Master, Wilhelmina, Iron III, Little Joss, Cambridge Browick, or Fox." The Yeomans, as explained above, are in a different category.

Rivet, or Cone, wheat—once the most widely grown of all English varieties, and still called "English" wheat in certain parts of Europe—is not strictly a bread-making wheat: it belongs to the species *Triticum turgidum*, and not to *T. vulgare*. Its bread has been described as execrable, and it is certainly singularly unappetizing, particularly its crust. However, it mills well, and a small percentage of it in all-English (non-Yeoman) grists is said by millers to assist materially the milling operations.

It should be pointed out, however, that there is a definite though limited demand by millers for wheats to be made into flour for other than bread-making purposes. Biscuit making on the one hand, and pastry and pudding flour and the self-raising flour trade generally on the other, both require soft flours, low in protein content, and of good colour. Yeoman wheat is quite unsuitable for these purposes, and it is here that Square Head's Master and the white wheats find their rightful market. Certain types of white English wheat, such as Queen Wilhelmina, are supremely good for biscuit making. All-English is not completely satisfactory for self-raising flours, but it frequently forms the major portion of mixed grists designed for self-raising purposes, the rest of the grist consisting of such imported wheats as Australian, or the relatively weak Pacific Coast American wheats.

English wheat growing, therefore, should embrace the cultivation of two distinct types of wheat, each to be grown in the districts where it is required, and sold for the declared purpose for which it is suitable. In this way soft English wheat would no longer glut the local markets or, alternatively, cease to be grown, and the farmer would not only obtain a better price for either his stronger or softer wheat, but he would better serve the interests of his colleague—the country miller.

["Flour Quality: Its Nature and Control," E. A. Fisher, London, 1929. "The Improvement of English Wheat," A. E. Humphries Liverpool, 1906; also (with R. H. Biffen) in *J. Agric. Sci.*, vol. ii., 1907. Annual Reports of Home-Grown Wheat Committee from 1901; particularly the Chairman's Report on Yeoman Wheat (1920); Quality of Red Fife Wheat grown successively in England for twenty-one years (1923); Reports on Various Forms of Wheat (1925, 1926, 1928, 1930, published in *J.N.I.A.B.*). "Wheat Breeding Investigations at the Plant Breeding Institute, Cambridge," R. H. Biffen and F. L. Engledow, *Min. of Agric. and Fish.*, Research Monograph No. 4, 1926.]

E. A. F.

WHEAT (*Continued*)—

DISEASES OF CEREALS—Although the fungal diseases from which British cereal crops suffer are numerous, they do not occur as devastating epidemics, and only rarely do they cause anything approaching complete loss of individual crops. Nevertheless, they reduce the yield of cereals, in the aggregate, by at least 10 per cent. The relative freedom from serious damage such as often occurs in foreign countries is due largely to the practice of crop rotation, and to the methods of disease control in general use. (See Rotations.) Of the factors involved in the prevention of disease in cereal crops, the soil (more especially its fertility and drainage) and the seed are of primary importance, and these, fortunately, are largely under human control; climatic conditions, also an important factor, can be met only to a limited extent by growing varieties suitable for the districts; protection of the growing crops against diseases is, generally speaking, impracticable. Up to the present the development of improved seed has been directed almost wholly to considerations of vitality, quality, productiveness, and adaptability. These good points may, however, be completely nullified unless due attention be given to the matter of disease, both in regard to inherent resistance to, and freedom from, disease. The first of these problems is of particular importance in counteracting wind-borne parasitic diseases, since, as already stated, protection of growing cereals is impracticable. Biffen's success in the production of the Rust-resisting wheat Little Joss marked the beginning of considerable advance that has taken place in other countries, but, up to the present, no other cereal with marked resistance to any disease has been raised in this country. The second problem, freedom from infection and contamination, is closely linked up with appropriate seed disinfection. This has been solved to a satisfactory extent for some seed-borne diseases, viz., those amenable to dressing of the seed with suitable fungicides, generally spoken of as "pickling," but suitable methods for the control of other seed-borne diseases have yet to be evolved. (See Seed, Transmission of Plant Diseases by.) As the control of the principal diseases will, for many years to come, be dependent on appropriate seed treatment, it is of interest to note that there are continual improvements on old methods and addition of new ones. So far as concerns diseases that are principally soil-borne, *i.e.*, those persisting in the soil, crop rotation has proved a fairly efficient safeguard. There is, for example, no Smut-infested soil such as occurs abroad under continuous wheat cropping. The soil-inhabiting parasites in this country are largely reduced in the interval between straw crops, and, with an extended rotation in cases of necessity, they rarely assume undue importance.

Some reference must be made to the "biological forms" of the fungi causing diseases. Suppose A, B, and C represent three varieties of wheat, and X, a parasitic fungus, be represented by X_1 from one country or part of a country, and X_2 from another area, there being no visible difference between X_1 and X_2. It might be found that X_1 infects A and B, but not C, whilst X_2 infects B and C, but not A. Then X_1 and X_2 would be considered "biological forms" of one

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fungus. In an area where X_1 was the dominant type, variety C would remain free from attack, but it would not remain free in an area where X_2 was dominant; variety B would suffer in both areas. Therefore, a variety may show resistance in one area but not in another, or it may show no resistance in either. Since there are "biological forms" of most of the cereal pathogens, this matter is of the utmost importance in relation to the production of varieties resistant to definite diseases. Further, the remarks apply to the different cereals also; *e.g.*, the Smut of wheat does not attack oats, the Yellow Rust of barley does not attack wheat, and so on, although there are Smut and Yellow Rust on both cereals. The matter is much more complicated than this simple explanation would suggest, but limitation of space precludes its further consideration here.

The Rusts. Yellow Rust (*Puccinia glumarum*), the commonest form in this group, is the most prevalent of all the diseases of cereals also. It appears about May as pustules of yellow uredospores on dead spots or stripes on the leaves. These spores serve to disseminate the disease through the crop, and over wide areas, throughout the summer. The damage done is the destruction of leaf tissue, followed by reduction in size of grain in proportion to the severity of attack. In severe cases, when the chaff and grains are attacked also, the latter are shrunken, sometimes "rusted," of lower quality, and give a poor yield. Towards autumn the uredospores are replaced by dark-coloured teleutospores. These spores appear to take no part in the cycle of the disease, since they cannot infect cereal plants and no other host is known. The fungus persists through the winter by passing to small self-sown plants, and from these to autumn-sown crops, where it lies dormant in the plant tissues until spring. Obviously, "pickling" the seed grain will not prevent this disease appearing in the crop.

Soil and weather conditions greatly influence the intensity of Yellow Rust attacks. The variety Little Joss, bred to resist this Rust, is not appreciably affected by it. Although frequently showing abundant flecks where Rust spores have germinated on the leaves, the plants bear but few spore pustules subsequently, because the parasite can establish itself only sparsely and feebly. Most other English wheats are but moderately resistant, whilst some are very susceptible, and all are liable to suffer severely on deep, heavy, or loamy soils, and on land in high condition. In localities unsuited for the growth of Little Joss, but where a Rust-resisting variety is required, Swedish Iron frequently proves successful.

Yellow rust occurs also on barley and rye, but the form on each cereal is a specialized biological form that does not attack another cereal.

Black Rust (*Puccinia graminis*), extremely destructive in Australia, America, and elsewhere, occurs in many parts of the British Isles, but it appears late in the season and does little damage. The reddish-brown Rust stage appears about July, as short, dust-filled spots on

WHEAT (*Continued*)—

the leaf blades, stems, and ears, but especially on the leaf sheaths. This is followed later by a black teleutospore stage, conspicuous along the stems as long, open, black wounds, from which the common name is derived. Secondary spores, produced by the teleutospores in spring, attack the barberry of hedgerows (rarely cultivated species) and form the yellow "cluster-cups" or æcidia; the spores from these infect cereals and reproduce the rust phase. In many countries no æcidial stage is produced or required for the perpetuation of the fungus; it overwinters after the manner of Yellow Rust, or by means of its "rust" spores, which, under cool and moist conditions, retain vitality for three months. Black Rust is believed to persist through winter in living cereals to some extent in this country, but the disease is undoubtedly more prevalent where barberry bushes are available for the æcidial stage of the life cycle.

In England there appear to be two biological forms of Black Rust of importance, one on wheat, barley, and to slight extent oats, the other on barley, rye, and couch grass (*Agropyrum repens*). Several kinds of wild and cultivated grasses are also affected, but the biological affinities of these Rusts are not fully known. All the forms have æcidia on barberry.

Control of Black Rust is being achieved abroad by breeding resistant varieties, and attempts are being made to control it by dusting the crops with fungicidal powders such as sulphur.

Other Rusts affecting cereals are Brown Rust (*P. triticina*) of wheat, with æcidia on Thalictrum under experimental conditions; Crown Rust (*P. Lolii*), with æcidia on buckthorn (*Rhamnus catharticus*) of oats; and Dwarf Rust (*P. anomala*) of barley. These, like *P. graminis*, appear too late in the season to do appreciable damage.

The Smuts—The Smuts of wheat, barley, and oats are seen in the ears when the grains are replaced by the spores, or "Smuts" of the fungi. Bunt of wheat (*Tilletia Caries*), the covered smut of barley (*Ustilago Hordei*), and the Covered Smut of oats (*U. Kolleri*) constitute a group in which the spores are retained within the chaff or glumes until the crop is threshed. Bunted ears are recognized by their slightly darker colour and spreading glumes, and the replacement of some or all of the grains by brownish "butts," each containing millions of fœtid, slightly greasy spores. Covered Smut in barley may be recognized by the brown ears and their spore masses much like those of Bunt, but the Covered Smut of oats differs from both in appearance, the spikelets being black with sooty spores. The spores are liberated in the thrashing machine and distributed violently over the healthy grains, thereby spoiling the colour, and with Bunt the odour, and lowering the value of the sample. If such contaminated grain be sown the seedlings are pierced by germ-tubes produced from secondary spores borne on an outgrowth of each original spore. There is no infection at any other stage of growth. Thereafter the fungus grows unseen within the affected plant, the only ill effect being reduction in length of straw, until spores are formed where the grains should be.

WHEAT (*Continued*)—

The amount of disease in a crop grown from contaminated seed will depend upon such conditions as the degree of contamination of the seed, and the moisture content and temperature of the soil at the time of sowing and shortly afterwards.

Since the Smut spores do not persist in ordinary cultivated soils for more than two or three months, disease in the crop is due solely to the spores adhering to the sown grain. In order to prevent this, these spores must be killed without harming the grain itself, if possible. This is done with wheat by "pickling" with copper sulphate or bluestone (2½ lbs. in 10 gallons of water), or with formaldehyde solution (1 pint of 40 per cent. strength in 40 gallons of water). These methods involving the wetting of the grain have disadvantages that induce some farmers to omit pickling. A dry method, dusting the seed with copper carbonate (4 ozs. per cwt. of seed), is now becoming increasingly adopted because of its several advantages, one being that dressed seed may be stored for any length of time after treatment without injury. In exhaustive trials carried out by the Advisers in Mycology in England and Wales, Bunt was produced from 22 per cent. in untreated seed to less than 1 per cent. when treated by any of the methods mentioned. The cost of materials ranges from about twopence to fivepence per acre. The Smuts of barley and oats are not controlled satisfactorily by the copper carbonate treatment, whilst pickling with copper sulphate often seriously reduces the germinative capacity. These grains should be treated, when necessary, by the "wet sprinkle" or by the "dry spray" formaldehyde methods, which are safe and efficient.

No British wheats show any resistance to Bunt, but the breeding of such wheats from resistant and immune forms found in Europe and America is proceeding in this country. Plants affected with Bunt are more than ordinarily susceptible to attack by Fusarium and by Rusts, hence Bunt-resisting wheats will be doubly advantageous; similarly, pickling the seed acts to some extent, indirectly, as a protection against diseases other than Bunt.

The second group of Smut diseases comprises those in which the spores are produced early in the season and are distributed while healthy plants are in flower. These are the Loose Smuts of wheat (*Ustilago Tritici*), of barley (*U. nuda*), and of oats (*U. Avenæ*). The spores are black, and after their dispersal the naked rachis of each affected plant remains visible. The spores reach the stigmas of the flowers of healthy plants, whilst the glumes and pales are parted at flowering time, and the fungus enters and grows in the developing grain, or between the pales and grain in oats, thereafter lying dormant until the grain is sown. The fungus then passes into the seedling and grows up with the plant, until it again forms spores in the ears. In Loose Smut of oats some spores remain in the spikelets until thrashing time, and behave like the Covered Smuts do, both as regards distribution of spores and mode of infection. "Pickling" does not control this type of disease, since the parasite is protected from direct action of the fungicide. A "hot" water method for treating such affected seed grain has been devised, but it is rarely used in this

WHEAT (*Continued*)—

country; if there is reason to think the seed grain is infected it is preferable to discard it and to use seed from a crop known to have been free from the disease.

It should be emphasized that the Smut on one kind of cereal cannot infect any other kind of cereal, in either field, granary, or machine, but so far as is known for British cereals the Smut of any one cereal will infect any variety of that cereal. Some of the Smut fungi are known to occur in biological forms restricted to particular varieties, but this knowledge is not yet of practical economic value.

Fusarium Disease and Whiteheads—Fusarium disease, long known on the continent of Europe and in America, is one of the least obvious and most insidious of the diseases of cereals. Of some twelve known species of Fusarium occurring on British cereals, the commonest are *F. culmorum* and *F. avenaceum*, whilst an allied species, *F. graminearum* (*Gibberella Saubinetii*), is now known to occur in various localities throughout England and in one place in Ireland. This last-named fungus causes great damage in the U.S.A. and in Europe, and its presence on European and Asiatic grain is known to render grain, flour, and meal toxic to man and beast. As there are certain known differences between the "strains" of this fungus in different parts of the world, the British and American "strains" may differ in toxic capacity; our knowledge of this question is as yet incomplete.

The phases of disease caused by the three species mentioned may, for practical purposes, be considered alike. They are: (1) a poor, thin stand, with death of many seedlings after brairding; (2) backward, yellowish, tip-withered plants in spring, that do not respond to satisfactory growing conditions; (3) failure to head out in barley and oats, and in wheat bleached ears, termed "whiteheads," with few or no grains; and (4) attacks on the ears of healthy plants, spoken of as "ear blight," causing absence of grains in one or many florets, or shrivelled or discoloured grains, some of which are non-viable. The ear blight phase is a result of direct infection by wind-blown spores, or by contact in stooks. The other phases arise either from infected seed sown in clean land or from healthy seed sown in contaminated land; the fungus makes its way from the seed or the soil to the base of the plant, where it causes rotting, resulting in the symptoms above mentioned. As regards infected seed, the infective material may be within the seed itself, or it may be external and amenable to the usual "pickling" processes. Grain from a crop showing much ear blight should not be used for seed. Fusarium thrives and persists in wet soils; for infested soils improved drainage, together with long intervals between straw crops and substitution of oats for wheat, is recommended.

Ophiobolus graminis, another fungus which causes Whiteheads, frequently occurs in conjunction with Fusarium, but in places is sometimes the main or the sole cause of the trouble. This fungus is usually observed as a thin, dark-coloured felt or film between the sheath and culm at the bases of affected plants. It does not extend

WHEAT (*Continued*)—

to the upper parts of the plants, hence at harvest is mainly left on the stubble. By setting the binder blades high, deeply ploughing in the stubble, and extending the period between straw crops, the disease can practically be eliminated. The dark-coloured fungus, *Cladosporium herbarum*, by some erroneously called a smut, is common on whitehead and other diseased plants. This fungus is merely a saprophyte, its presence indicating some other disease or else badly ripened grain.

Helminthosporium Disease and Blind Barley—Leaf Stripe, caused by *Helminthosporium gramineum*, is a common and destructive disease of barley. It occurs as brown stripes of dead tissue on the leaves, and sometimes on the ears. Badly affected plants are frequently dwarfed, whilst in others the awns may remain fixed within the sheathing leaf and the ear be only partially exserted; or, the exserted ear may be "blind," *i.e.*, contain few shrivelled grains or none at all. Spores produced on the diseased tissues reach the flowering parts of healthy plants, and develop mycelium between the pales and the grain; in later stages of ear formation the spores merely adhere to the awn end. The shoot of the seedling is attacked as it emerges, and the successive leaves, and finally the ear, become attacked as they grow past diseased external parts; hence the stripes on successive leaves. Seed treatment designed to kill externally-adhering fungus has been found fairly satisfactory as a control measure, but it is better perhaps that the grain from an affected crop should not be used for seed.

Leaf Spots of barley (*H.* (*Pyrenophora*) *teres*) and of oats (*H. Avenæ*) are somewhat similar to the Stripe disease, but are generally much less serious. Seedling oats are commonly affected, but they grow away from the attack under normal conditions. Leaf Blotch of barley and rye (*Rhyncosporium Secalis*), a brown discolouration at the base of the leaf blade and on the sheath, is also of minor importance.

Blindness in barley is a term more correctly applied to the absence of grain in one or more of the spikelets, whilst the remaining part of the ear is normal. The presence of *H. gramineum* instead of the ovary or grain shows another aspect of the Helminthosporium disease. In some districts and seasons such "gappy" barley shows no fungal cause, and is much more prevalent in some varieties than in others under the same conditions. This type of trouble has been attributed to infertility of the pollen, barley flowers being self-fertilized; but this explanation does not meet the majority of cases of Blindness. The main cause appears to be the insects thrips, that gain entrance to the florets and damage the structures; and this mostly in varieties having the pales open more widely and for a longer period at flowering time than in others. The use of "non-gaping" varieties and early sowing are means of reducing or avoiding the trouble which occasionally reduces the crop by as much as 30 per cent.

Ergot of Rye—Ergots are horn-shaped, purplish-black structures which take the place of grains in rye, occasionally in wheat, oats,

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and barley, and frequently in rank grasses of hedgerows, roadsides, and old grass land. The fungus *Claviceps purpurea* is believed to have two biological forms, the one on rye attacking wheat only rarely and feebly. It gains entrance to the florets when the pales are open at flowering time, and reduces the yield of grain, not only where ergots are formed, but also by causing barren florets and shrivelled grains. The ergots are poisonous to man and beast. They cause paralysis, gangrene, etc., and death in animals, and are supposed to cause pregnant animals to abort. Rye bread, used largely abroad and to some extent by Jewish communities in this country, has somewhat similar ill effects on human beings when prepared from ergotted grain. "Soiling" crops containing affected rye, and "seeding" grass on affected pastures, should not be fed. Seed containing ergots should never be sown.

Grey Spot of Oats—This trouble usually appears as grey spots of thin tissue, generally towards the middle of the leaf blades, or as reddish, then grey stripes along the blades, after plants have passed the seedling stage. Affected leaves may break across or wither entirely, in either case preventing the full development of the ears and grain. The trouble is not due to living organisms, but is physiological, resulting from certain soil conditions. It is sometimes associated with over-limed soils, in which manganese becomes unavailable for plant use, and with long cultivated soils in which this element is deficient. It is then remedied by dressing with manganese sulphate and the use of acid fertilizers, lime and basic manures being avoided.

Grey spot also occurs on certain soils reclaimed from bog, fen, or heath land, and when peaty humus is brought up in the ploughing of "natural" grass land. The deleterious humic matter is modified by dressings of compost and copper sulphate; when corrected, lime deficiency usually becomes apparent, and lime and basic fertilizers should then be used, but not before completion of the corrective treatment. (See Peat Land.)

Grey spot "disease" affects wheat and barley slightly, but white oats are far more sensitive to it. The symptoms vary for different plants and on different soils, and the trouble must be dealt with according to local soil conditions.

Miscellaneous—There are a number of diseases of lesser importance, though in places of frequent occurrence. Mildew (*Erysiphe graminis*) attacks the lower leaves and stems in damp situations; the Mildew on each cereal is a specialized biological form. Septoria may be seen as minute black dots (spore cavities) in small, discoloured patches on the leaves (*S. Tritici*), and on the stem nodes and ears (*S. nodorum*) of wheat; other species affect oat, barley, and rye leaves. All cereals exhibit abundant vegetative development when they are supplied with large quantities of nitrogen. Under these conditions attacks of mildew are common; they may be mitigated, however, when potash in some form is used in conjunction with the nitrogenous fertilizers. Twist (*Dilophospora Alopecuri*) occurs as a blackish-brown, crust-like weft

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on the leaf sheaths, and on the ears of wheat, the latter being thereby distorted. Brown Neck of wheat and Halo Blight of oats are examples of troubles not yet elucidated.

Two standard textbooks on plant diseases are: "Plant Diseases," by F. T. Brooks, M.A., F.R.S., Oxford University Press; "Fungi and Plant Diseases," by F. T. Bennett, B.Sc., Ph.D., Macmillan and Co., London.

F. T. B.

INSECT PESTS OF CEREALS, The Treatment of—The small profit obtainable from any cereal crop limits the amount which can be spent on the control of cereal pests. As a consequence, many of the measures for keeping these pests in check are of an indirect nature, *i.e.*, they aim at making conditions unfavourable to the pest or favourable to the crop, or both.

Cereal pests may be divided into two groups: (*a*) specific pests, *e.g.*, Frit Fly, Wheat Bulb Fly, Gout Fly, which attack only cereals and grasses; (*b*) general pests, *e.g.*, Wireworm, Leather Jackets, and Cutworms, which attack cereals and grasses in addition to a number of other crops.

The Frit Fly (*Oscinella frit*) is responsible for serious losses to cereal crops throughout the British Isles and in Central and Northern Europe, and is also injurious in Canada and the United States of America. Its attack varies considerably in intensity from year to year.

It attacks all cereal crops, and in addition can be found on a number of grasses, especially rye grass (*Lolium perenne*), which serve as a natural reservoir. (See Frit Fly, and Oats.)

The Frit larva feeds on the central shoots of the tillers of the cereal plant and kills it. The damage is often confused with attacks of the Stem Eelworm (*Tylenchus dipsaci*), but it may readily be distinguished by the yellowing of the central shoot, while the older leaves remain green. The presence in the shoot of a creamy, shiny larva, about ⅛ in. long, and with thin mouth parts, will confirm the presence of Frit Fly (*cf.* Wheat Bulb Fly). Some of the larvæ also feed on the young soft grain.

In the British Isles this pest produces three generations of flies every year: (1) The first generation lay their eggs on spring oats (sometimes on barley and wheat) and on certain grasses. The damage caused by the larvæ to late-sown oats is very severe in some seasons. (2) The second generation of flies appears in July, and these lay their eggs on the ears of oats or on young grasses. (3) The third generation of flies appear in August and September, and lay their eggs in grasses or "volunteer" cereal plants. When a grass ley is ploughed under, the maggots leave the grasses as they decay and attack winter corn if this follows the ley (F. R. Petherbridge, *Ann. App. Biol.*, iv., 1927).

Control—Frit Fly is difficult to control, as it is able to live entirely on certain grasses which are abundant in most districts, and is able to migrate from them to cereals.

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In a series of papers in the *Annals of Applied Biology,* Cunliffe has given the results of numerous experiments and observations on this pest. As a result of this work he has decided that the most likely solution of the problem of controlling Frit Fly is to be found in the breeding (or discovery) of a variety or varieties of oats comparatively resistant to attacks.

Cunliffe, Fryer, and Gibson (*Ann. App. Biol.*, xii., 1925) have shown that in the case of oats the susceptibility of the main stem to attack is found to be most marked during the two and three leaf stages of growth, and they suggest that the selection of a variety which passes rapidly through these stages may provide a practical solution of the Frit Fly problem.

The Plant Breeding Institute at Cambridge are attempting to breed improved varieties of winter hardy oats, more particularly varieties with stiffer straws than obtain in our present winter varieties. These varieties should prove very useful to farmers in districts where Frit Fly damage is severe.

At present, the best means of reducing the damage to spring oats is to sow early, always provided the tilth is suitable.

The following results obtained on the Cambridge University Farm in 1923 (Petherbridge, *J. Min. Agric. and Fish.*, January, 1924) show the importance of this procedure:

		Yield per Acre in Cwts.	
Oats.	*Date of Sowing.*	*Grain.*	*Straw.*
Seeded at 3 bushels per acre:			
Plot 1	Feb. 1	16·0	42·7
,, 2	Feb. 20	14·9	31·0
,, 3	March 1	15·2	29·3
,, 4	March 15	10·7	25·1
Seeded at 4 bushels per acre:			
Plot 5	March 23	9·9	25·3
,, 6	March 31	6·2	18·1
,, 7	April 14	2·0	8·8

The damage to winter corn can be prevented by the following means:

1. Ploughing grass leys before September (*i.e.*, before the eggs are laid on the grasses).
2. Omitting grasses from the leys and growing only clovers or sainfoin.
3. Altering the rotation so that winter corn does not follow a grass ley.

The deep ploughing of an infected ley is not likely to destroy this pest, as Blunt and Ludewig (*Georgine, Land- u. Forstw. Ztg.*, No. 25) have shown that the larvæ can travel from plants buried to a depth of 12 in. through clay soil that has been firmly stamped down, and reach the new crop.

The Wheat Bulb Fly (*Leptohylemyia coarctata*) is common throughout the whole of Britain, and in some years causes serious damage to winter wheat; there are in addition several records of serious damage

WHEAT (*Continued*)—

to winter barley. Couch grass (*Agropyrum repens*) can also serve as a host to this pest.

The damage in this case is similar to that caused by the Frit Fly in that the central shoot is killed and turns yellow, while the older leaves remain green. The larva present in the shoot in this case is whiter, larger, and has larger jaws and possesses prominent tubercles at its tail end.

Investigations into the habits of this pest indicate the conditions under which an attack may be expected, and also, to some extent, how it may be avoided.

Fen soils and heavy soils generally suffer most severely from this pest.

The worst attacks are almost always on land which was a bare or bastard fallow in the previous season, or carried a root crop, *i.e.*, land that was not completely covered by a crop during the latter part of the summer.

Petherbridge (*J. Agric. Sci.*, vol. xi., 1921) and Gemmill (*Scot. J. Agric.*, vol. vi., 1923) have shown that this pest has only one generation per annum, and the eggs are laid in July, August, and September just below the surface of the soil, on bare land or land not greatly shaded by crops.

Control—From what has been shown above, it will be seen that there is a risk in sowing wheat after fallows or crops in which the land is not well covered in late summer; this risk is said to be greater after a hot, dry summer. If wheat is sown on such fields, it is advisable to sow early in order to get the plants tillered before the attack starts in the early spring. Plants with several tillers usually recover, whereas those with one tiller are usually destroyed. For a similar reason a firm tilth is likely to give better results than a loose tilth.

Where fallows are sufficiently clean by the end of June or early July, a crop for ploughing in or feeding off may be sown in order to cover the land during the time that the wheat bulb fly lays its eggs. Mustard is probably the best crop for this purpose.

If the winter wheat or barley is so badly attacked that it is considered advisable to plough it in, barley or another cereal crop may be sown without fear of attack.

The Gout Fly (*Chlorops tæniopus*) is common throughout the British Isles, but is not such a serious pest as either Frit Fly or Wheat Bulb Fly.

Barley suffers most from this pest, but wheat and rye and certain grasses, especially couch grass (*Agropyrum repens*) may also be attacked.

The damage consists in the burrowing of the larva down the side of the ear and to the uppermost node of the culm. As a result of this, the ear usually does not mature, but remains inside the twisted leaves so that the shoot becomes swollen and gouty.

There are two generations per annum. The first generation of flies lay its eggs on the developing ears of barley (and occasionally of wheat) in May and June. The majority of the second generation of flies emerge during August, but a few may be much later.

WHEAT (*Continued*)—

These flies lay their eggs chiefly on couch grass (*Agropyrum repens*), but occasionally on autumn-sown corn or "volunteer corn," and the maggot passes the winter in these plants.

Control—Several observers have shown that Gout Fly attacks are worst on late-sown spring barley or on barley that is not doing well. Early sowing, combined with good cultivation, is therefore of primary importance in reducing the damage in fields where the pest is troublesome.

Frew (*Ann. App. Biol.*, xi., 1924) has shown that certain manures (particularly superphosphate) have a marked beneficial effect in reducing the infestation of spring-sown barley by Gout Fly. The effect of the manures is shown to be due entirely to their stimulating effect upon the maturing of the ear and the growth of the ear-bearing internode. He suggests the following preventive measures: (1) Early sowing of spring barley; (2) good cultural conditions of the soil; (3) manuring (*e.g.*, with superphosphate or farmyard manure) to stimulate early growth.

Stem Eelworm (*Tylenchus dipsaci*) is the cause of what is known as Tulip Root in oats.

The symptoms are the swelling of the base of the stems and usually failure to produce ears. (Frit Fly attacks are often attributed to Eelworms.)

The Stem Eelworm attacks a number of different plants, such as oats, clover, bulbs, and potatoes, but it is uncertain as to the extent to which those living on one crop are capable of adapting themselves to a new host.

Healthy crops of oats have been grown after clover attacked by Stem Eelworm, and red clover has been successfully grown from seed in a crop of oats infested with Stem Eelworm. Healthy wheat plants have been grown in this country next to badly infested oats, but on the Continent wheat and rye are said to suffer from Stem Eelworm attacks. The Stem Eelworm from onions is capable of attacking oats.

These observations suggest that there are different biological strains of the Stem Eelworm, and if this proves to be the case, it should be possible to starve out the Oat Eelworm by planning the rotation to include only plants that are not attacked by the oat Stem Eelworm.

The production of vigorous growth by the application of quick-acting nitrogenous manures is useful in reducing the damage caused by this pest. Potash manures are also said to be useful.

Wireworms are the larvæ of certain species of Click-Beetle. Rymer Roberts (*Ann. App. Biol.*, viii., 1921) has shown that our commonest species (*Agriotes obscurus*) may live for five or six years in the "wireworm" stage.

They occur nearly everywhere, and attack almost every kind of crop. Their habit of killing a number of contiguous cereal plants by eating through the stems below ground is well known.

Wireworms are most troublesome when grassland or long leys are broken up, or when land has become foul.

WHEAT (*Continued*)—

Roebuck (*J. Min. Agric. and Fish.*, xxx., 1924) has shown that no serious damage occurred on cereals until the Wireworm population of the soil exceeded 200,000 per acre.

The crops which usually suffer very little from Wireworm attack are mustard, linseed, and beans. Peas (if broadcast) are a fairly safe crop, and buckwheat, rape, and cabbage have given good crops on infested land. Potatoes, and especially early potatoes, often give a satisfactory yield where the infestation is not too great.

Where a bad attack is feared, it is wise to confine the cropping to those mentioned above until such time as the Wireworm population has been reduced to the safety limit by good cultural methods.

Roebuck has also shown that when grass land is ploughed up and well cultivated, the Wireworm population is gradually reduced (a Wireworm population of 900,000 in 1915 was reduced to 6,000 in 1922). He also says: "Five years' cultivation appears to be sufficient to reduce the Wireworm in ploughed-up pastures to unobjectionable proportions." He has on two occasions reduced to a negligible quantity in one season Wireworm contents of 300,000 and 350,000.

Oats are the most satisfactory cereal crop for Wireworm infested land.

A good firm seed bed reduces Wireworm damage by encouraging plant growth and restricting the movement of the Wireworm, consequently any cultural operation which assists consolidation of the seed bed will help the crop to withstand an attack.

There is no experimental evidence to show that the use of chemical insecticides is an economic proposition on agricultural land, although it is possible that they may be useful to the horticulturist when large dressings can be used.

Rape cake has been recommended to attract the Wireworm from crops, but Spuler (*J. Econ. Ent.*, vol. xviii., 1925) has shown that germinating seedlings attract more Wireworms than any other bait. Miles and Petherbridge (*Ann. App. Biol.*, vol. xiv., 1927) have shown that young wheat plants are more attractive than any of the ordinary baits, and that a large percentage of the Wireworm population may be attracted to rows of wheat about 3 ft. apart, and most of these killed by drilling calcium cyanide up the wheat rows when the wheat plants are about 3 ins. high. This is too expensive for agricultural land, but is useful in glasshouses.

Leather Jackets are the larvæ of various species of Crane Flies or Daddy Longlegs (*Tipula* spp.).

In cereal crops they attack the grain, roots, or stem. They cause most damage after grass or leys, but this may be largely obviated by ploughing up immediately after the hay crop is harvested, and bastard fallowing, as the eggs are laid from June to September.

Consolidation of the soil assists a corn crop to grow away from an attack.

Good results have been obtained by means of a poison bait consisting of moist bran and paris green. One lb. of paris green should be

WHEAT (*Continued*)—

thoroughly mixed with 20 lbs. of bran and sufficient water (about a gallon) added to moisten the mixture. The bait should be broadcast at the rate of about 30 lbs. per acre.

Cutworms or Surface Caterpillars are the larvæ of various species of Noctuid Moths (mainly *Agrotis* spp.).

In cereal crops they cut off the plants at about the ground level; they are especially troublesome on foul land.

Cereals after a fallow or bastard fallow do not usually suffer from Cutworm damage.

Poultry are very fond of these caterpillars, and a good method of checking the pest is to run poultry on infested land.

Good results have been obtained from the use of poisoned bait consisting of moist bran and paris green. One lb. of paris green should be thoroughly mixed with 20 lbs. of bran and sufficient water (about a gallon) added to moisten the mixture. The bait should be broadcast at the rate of about 30 lbs. per acre.

Slugs, of which the worst offender is the Grey Field Slug (*Agrolimax agrestis*), are often responsible for serious damage to winter corn. They are especially troublesome in mild winters on heavy soils, as under these conditions they continue to feed at a time when the plants are making little growth. They have rasping tongues, and as a consequence, leaves on which they have been feeding are not clean cut, but eaten off in an irregular manner, and often show the veins from which the green part of the leaf has been eaten. They sometimes cut off the plant at, or below, soil level.

Ducks are fond of slugs, and can be utilized to reduce these pests.

Anderson and Taylor (*Leeds University Bull.*, No. 143) killed a large number of slugs in field experiments in which they applied a finely ground mixture of 6 lbs. of copper sulphate and 1 cwt. of kainit at the rate of 3 cwts. per acre. This treatment is only efficacious if applied at night when many of the slugs are above ground.

Good results have also been obtained by broadcasting a poison bait on cereal crops attacked by slugs.

The bait is made by mixing 1 lb. of paris green with 20 lbs. of bran and then adding sufficient water (about a gallon) to moisten the mixture. Thirty lbs. is sufficient to dress an acre. F. R. P.

WHEY—Whey is the liquid which separates from the curd when milk is made into cheese.

Although a thin, yellowish liquid, it contains almost all of the substances in solution in the original milk, amounting to nearly half the total solids of the milk from which it was produced.

Its composition, as given by Berry (*J. Agric. Sci.*, vol. xiii., pp. 192-239, 1923), is:

	Per Cent.
Water	93·17
Fat	0·21
Milk sugar	4·80
Protein (chiefly albumin and globulin)	0·87
Ash	0·48

WHEY (*Continued*)—

The ash, which represents some 70 to 75 per cent. of the ash of the original milk, includes 22·4 per cent. of phosphoric acid, 12·5 per cent. of lime, 3·3 per cent. of magnesia, and 28·3 per cent. of potash.

Owing to its watery appearance and the cost of transport from urban creameries to the farms, much whey is wasted, which under the older conditions of farmhouse cheese making would have been fed to pigs and other farm stock. (For feeding value see Feeding Stuffs.)

The difficulty of transport is increased by the fact that under present conditions empty churns are sterilized at the factory, and as adequate provision for this purpose is not provided on the farm, the use of the milk churns for the return of whey is most undesirable.

The best method for dealing with factory whey is to dry it at a sufficiently high temperature to destroy bacteria.

This can be carried out on roller driers, and by the use of a preheating tank and evaporating sheets; the waste heat units from the boiling whey can be used for the purpose of concentrating the feed of whey to the rolls, thus increasing the output from each set of rolls. The pre-concentrated whey is more suitable for the process of roller drying than the original liquid. The dry powder produced can be used for bread making (see "The Utilisation of Dried Whey in the Milling and Baking Industries," *J. Min. Agric. and Fish.*, September, 1928). It can also be used for feeding pigs.

The use of a double effect condensing plant has also been developed by Dr. Leonard Harding ("The Whey Problem and a Solution," *Min. Agric.*, Research Monograph No. 5). By this process a part of the lactose can be recovered and purified.

The residue known as " whey paste " can be used with advantage for feeding pigs (see Golding and Morris, " Whey Factory Research at Haslington: Pig Feeding Experiments with Lactose Residues," *J. Min. Agric.*, vol. xxxii., No. 10, 1926).

J. G.

WHITE CURRANTS—See Fruits, Soft.

" **WHITEHEADS** " (**in Wheat**)—See Diseases of Cereals, under Wheat.

WILD WHITE CLOVER (*Trifolium repens* L., var. *sylvestre*)—**General Description of the Plant**—This species has a very wide geographical distribution. It is indigenous to all European countries, and to most of the temperate parts of Asia. It is also now commonly met with in most other temperate countries of the world—probably as an introduced plant; it is abundant in the British Isles.

The plant is a perennial, and grows prostrate on the soil surface. From its central primary tap-root arise solid creeping stems (stolons). These stems produce adventitious roots at their nodes and spread out in all directions over the ground. Owing to the closeness of the nodes the number of rooting points is very great, and under favourable conditions the plant soon covers several square feet with a very dense growth of stems and foliage.

The leaf stalks (petioles) arise alternately from the stolons, bear small stipules, and vary in length from one to several inches. They

WILD WHITE CLOVER (*Continued*)—

usually assume an erect position and have three leaflets (trifoliate). The leaflets vary considerably in form from obcordate to oval; their margins may be either partially or wholly entire or serrate (toothed). The leaves are usually glabrous, but slightly hairy forms sometimes occur. Pale whitish areas (horse-shoe marks) are generally present on the leaflets, but not invariably. The inflorescence is a rather compact globular head (umbel) of white flowers. These terminal heads of flowers are carried on stalks (peduncles) which arise in the leaf axils and grow erect to a greater height than the leaf stalks. The five sepals are combined, but the five small narrow petals are free. Of the ten stamens the upper one is free. The seed pod (legume) contains from three to six seeds—usually four. On ripening, the short flower stalks (pedicels) curve backwards and downwards (reflexed), and the persistent corollas fade to a brown colour.

As with other widely distributed species numerous slight variations occur, and the above description must be read with this fact in mind. For example, the shape of the leaflets is very variable, and the flowers may be white, cream, pale yellow, or rose-pink in colour. A variety (var. *rubescens* Ser.), with deep lilac-purple flowers, is met with in the Scilly Isles and elsewhere. (For a full description of the varieties see "White Clover," a monograph by Adela G. Erith, Duckworth and Co., London; see also *Min. Agric. and Fish.*, Misc. Pub. No. 46, "White Clover," by W. M. Ware.)

Introduction into Agriculture—We do not know when the seed of this plant was first definitely sown for the production of permanent grass land, but it was earlier than is usually supposed. Edward Lisle in his "Observations in Husbandry," 2nd. edit., vol. ii., p. 55, 1757, mentions that a neighbour in Hampshire had "sowed the wild white and red broad-clover, or honeysuckle, and it holds the ground and decays not," the seeds of which he received from Sussex, where the culture of these was then practised. This was between the years 1693 and 1722, and is the earliest reference to the definite use of wild white clover the writer has met with.

When sowing land to permanent grass it was then, and also much earlier, the common practice to collect seeds from the hay carts or hay loft for the purpose. In his "Practical Treatise of Husbandry" (1759) M. Duhamel du Monceau says on the question of forming permanent grass: "The best seed for this purpose is the best sort of upland hay seed, taken from the cleanest pastures, where there are no weeds." Since wild white clover is an indigenous plant, quite common on most upland pastures, it is certain that some of its seed was included in "mixtures" obtained in this way.

The practice of collecting seeds from the best old pastures has indeed continued down to the present time and with much justification. About the year 1880 some seeds of perennial rye grass, crested dogstail, wild white clover, etc., taken from an old pasture in Kent were sown alongside other "mixtures" in experimental plots on the Hawarden Estate in Flintshire. The luxuriance and persistency of wild white

WILD WHITE CLOVER (*Continued*)—

clover in this plot attracted much attention for years. But it was the effect of basic slag that really led to the modern extensive use of wild white clover for pasture formation. In 1897 an attempt was made to improve poor grass land on boulder clay at Cockle Park in Northumberland by the use of various fertilizers. It was found that heavy applications of basic slag produced the greatest and most rapid improvement as actually measured by the live-weight increase of sheep fed on the plots. Further, it was quite evident that this rapid improvement was due to the stimulus given to leguminous plants present —the principal one being wild white clover. This result was confirmed and amplified by numerous experiments soon afterwards in all parts of Britain. In the early years of the twentieth century the harvesting of wild white clover seed had become a regular and increasing practice, and the leading seed firms definitely offered it in their catalogues.

Valuable Agricultural Features of the Plant—In this single species are combined many valuable characters which make it especially suitable for grazing conditions in permanent pasture.

1. *It is a rapid soil coverer,* and thus helps to exclude weeds in the early stages of grass formation.
2. *Its prostrate habit* enables it to grow in close contact with the surface soil, and therefore blend in well with other suitable pasture plants. Its dense mat-like growth binds together the turf and helps to conserve soil moisture.
3. *It thrives under the treading of livestock.* Except where treading is quite excessive the plant benefits; for a moderate amount of breakage of the runners, or of the ground surface, only serves to give the plant fresh opportunity for growth.
4. *It can withstand close grazing without injury.* The growing terminal shoots of the ever-spreading runners are constantly producing fresh leaves, which take the place of the older ones as they are eaten.
5. *Its foliage possesses a very high nutritive value.* As pasturage it supplies a rich and highly digestible food for livestock.
6. *It greatly improves the fertility of the soil,* owing to the associated organisms in its root nodules, which bring about the fixation of the free nitrogen of the air. The great abundance of the nodules on the numerous adventitious roots makes this plant one of the most effective "nitrogen gatherers" for the farmer. The increased fertility assists the growth of the grasses associated with it in a pasture.
7. *It is a good drought-resisting plant.* When once a turf has been established, it will seldom suffer seriously, except on sands or gravel in districts of low rainfall. Its primary tap root enables it to persist under fairly dry conditions, though its production under such circumstances is much reduced.
8. It is capable of thriving under a wide variety of conditions of soil and climate.
9. *It is less subject to diseases or pests than perhaps any other extensively cultivated agricultural plant.* This is of immense importance in

WILD WHITE CLOVER (*Continued*)—

the case of a permanent pasture plant. It has been known to be attacked by *Sclerotinia trifoliorum* (one of the diseases causing "clover sickness") when growing luxuriantly in plots situated on rather damp clay arable soil; but attack by this disease is of very rare occurrence indeed in a pasture.

10. Lastly, *it is a perennial,* and under suitable conditions the plants persist for many years. Owing to the gradual replacement which occurs in a pasture the plant, once established, continues as long as required.

The Plant's Requirements—(*a*) *Climate*—A moist, humid, and mildly temperate climate is most suitable. Moderate spells of drought, while not fatal, very much hinder development and curtail production. Where the rainfall is below 20 ins. per annum the growth is usually limited, unless the soil be very retentive of moisture.

The seed should not be sown later in the autumn than September, particularly in the northern part of Britain, as the young plants may suffer from frost damage. When well established the plant is seldom permanently injured by the lowest temperatures experienced in these islands.

(*b*) *Soil Conditions*—Soils that by reason of their texture, or situation, can maintain a more than moderate supply of moisture in their upper layers are the most favourable for the development of this plant. This is because it is (in the main) a surface-rooting plant, and for rapid growth its supply of moisture and nutrients must be readily within its reach. This explains why many of the stiff clay soils in the east of England, with their defective top drainage, provide such an excellent habitat for the plant when they are properly manured. Retentive clay soils are almost always suitable, but fairly deep loams, calcareous soils, and even chalk—provided it is sufficiently moist—afford good conditions for its development. On sands and gravels it usually does not thrive, though where the rainfall is high it may do well even on soils of fairly open texture. Nor does it thrive on soils having an acid reaction. It is seldom found on peat or black peaty soils, perhaps partly because of the low mineral content of such soils, and partly because of the poor root hold afforded by the loose top layers of such soils.

(*c*) *Fertilizers*—Numerous manurial experiments conducted on grass land have demonstrated the requirements of this plant (see T. H. Middleton, "The Improvement of Poor Pastures," *J. Agric. Sci.*, vol. i., p. 122). An ample supply of phosphates is of prime importance for wild white clover. Many of the worked-out stiff clay soils of Britain are very deficient in phosphates, and on such soils basic slag produces striking results through the stimulus given to this plant. Where the herbage is very thin and loose, it has generally been found that an initial dressing of 10 cwts. per acre gives better results than two dressings of half the size given with an interval of three or four years. The transformation is the more sudden and complete when the initial application is large, since it enables this clover to crowd

WILD WHITE CLOVER (*Continued*)—

out more completely the weeds and inferior plants. By about the third season the better pasture grasses begin to benefit (indirectly from the clover growth), and their increase leads to the production of a more balanced herbage.

Mineral phosphatic manures—provided they are finely ground is may be used with good effect; so also may superphosphate, if lime—also applied to counteract its acid tendency.

The use of lime by itself, even in large quantities, is usually ineffective and unprofitable. It may, however, be a first necessity on such soils as are known to have a highly acid reaction—as, for example, are common in the manufacturing areas of Yorkshire and Lancashire. White clover requires alkaline soil conditions for its best growth.

On most clays and loams potash fertilizers are not required; but on many of the lighter types of land the use of potash, in conjunction with phosphates, is necessary for the full production of the plant.

Nitrogen—as such—is not harmful to wild white clover. Nevertheless, when nitrogenous fertilizers are applied in appreciable amounts to grass land, the growth of this plant is retarded, and its proportion in the herbage diminished. This is especially the case when applied in the form of sulphate of ammonia, though it is also the case when nitrate of soda or nitro-chalk, etc., are used, or when oilcakes or meals are largely fed to grazing animals. This suppression of wild white clover is due largely to the increased stimulus given to the grasses, which can therefore compete on more favourable terms with the clover, and to a greater or less extent tend to smother it by their taller growth, In the case of sulphate of ammonia another factor comes into play, Owing to its finely crystalline condition this fertilizer produces a direct plasmolysing action on the broader leaves of the clover and weeds, *e.g.*, buttercups, and by this means directly suppresses them at the same time as the grasses are stimulated. This action is greatly intensified when it is applied during fine warm weather.

When improving poor pastures, where the herbage, though of an inferior type, is still rather dense, it has been found that drastic surface cultivation is a valuable and sometimes essential adjunct to the use of mineral fertilizers as described above. Special turf "rejuvenators" are now designed for this type of work, though disc or heavy tined harrows may sometimes answer well. The value of such cultivations depends largely upon the fact that they enable the wild white clover present to gain an increased root hold on the freshly exposed soil.

(*d*) *Grazing and General Management*—Reasonably close grazing is beneficial to this plant, since taller growing and coarser plants are thereby prevented from excluding light and air. Generally, grazing should be heavy enough to prevent the plant flowering, *i.e.*, up to August, after which it may be allowed some freedom of growth. It is unwise, however, to graze it too closely in early spring or in periods of very dry weather.

The efforts of the grazier should be directed towards the establishment and maintenance of a *blend* of grasses with wild white clover. If a pasture yields herbage containing from 20 to 30 per cent. of this clover,

WILD WHITE CLOVER (*Continued*)—

it is doubtful if anything will be gained by increasing this proportion. Something like this proportion should, however, be maintained by suitable manuring and management. Where areas of coarse grass (foggage) occur in a pasture, cutting in autumn with a scythe will do good; as will also the spreading of droppings, and the use of the roller in spring.

Its Use in the Formation of New Grass Land—The difficulty and uncertainty of pasture making up till near the end of the nineteenth century were in large measure due to a lack of knowledge of the value of wild white clover and the use of phosphates in stimulating its growth. Today, with this knowledge, the formation of a good turf is a rapid and certain process on most soils. For permanent pasture, from 1 to 2 lbs. of seed per acre of wild white sown with five or six other suitable grasses and clovers will, with careful management as regards grazing, etc., usually meet all requirements. For the best results this plant *must* be included; if cost is a serious consideration, it is better to exclude or reduce some of the other species than to omit this clover. For leys of two years or longer duration, and for temporary pastures generally, the seed should be included. Usually 1 lb. per acre is sufficient. (See Seeds Mixtures.)

Seed and Seed Supply—Seed of genuine wild white clover may be distinguished from the ordinary Dutch white by the following features (see Plate XXV, Figs. 1 and 2):

(*a*) *It is slightly smaller in size.* Dutch white has a range of 1,400 to 1,600 seeds per gram, the average number being rather over 1,500. Wild white clover seed has a range of 1,700 to 2,000, or even more, seeds per gram, with an average of approximately 1,900.

(*b*) *The seeds are more rounded in outline,* the groove between the radicle or cotyledons being less distinct.

(*c*) Genuine wild white seed from old pastures invariably *contains characteristic impurities, i.e.,* the seeds of such plants as are associated with it in old turf. Seeds of such plants as yellow suckling clover (*Trifolium dubium*) (Plate XXV, Fig. 4), bird's-foot trefoil (*Lotus corniculatus*), self heal (*Prunella vulgaris*), crested dogstail (*Cynosurus cristatus*, L.), Yorkshire fog (*Holcus lanatus*), and bent grass (*Agrostis stolonifera*), are commonly met with in samples of genuine wild white.

Until recently it was believed that the chemical test for the cyanophoric reaction would distinguish between the seeds of wild white and Dutch clover. Investigations by Adams at Aberystwyth, however, indicate that both positive and negative reactions are commonly obtained from different individual seedlings of the same sample, or even from the same plant. Adams's paper published in the *Ann. of Appl. Biol.*, vol. xiii., p. 339, entitled "Some Observations on White Clover, and a Method of Distinguishing between the Seeds of Wild White and Dutch Clover," and Wm. M. Findlay, "Chemical Test for Wild White Clover," *Scott. J. Agric.*, April, 1927, are well worth consultation by those who desire to differentiate between these two varieties.

PLATE XXV

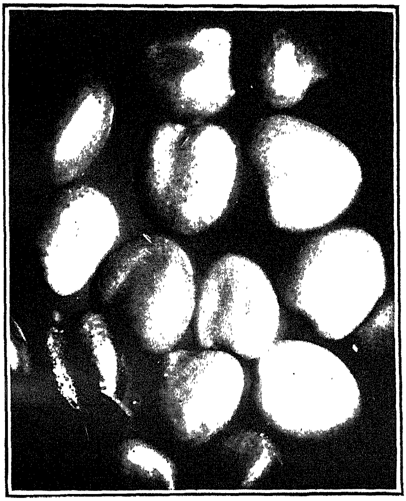

FIG. 1.—DUTCH WHITE CLOVER. × 10.

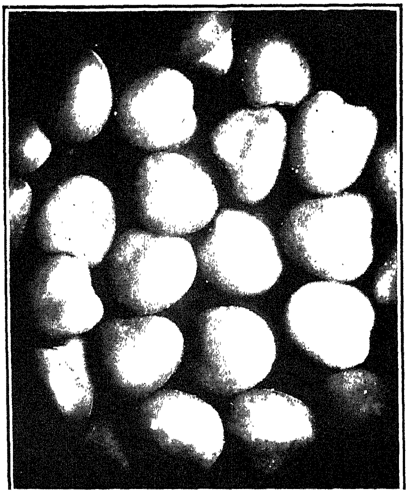

FIG. 2.—ENGLISH WILD WHITE CLOVER. × 10.

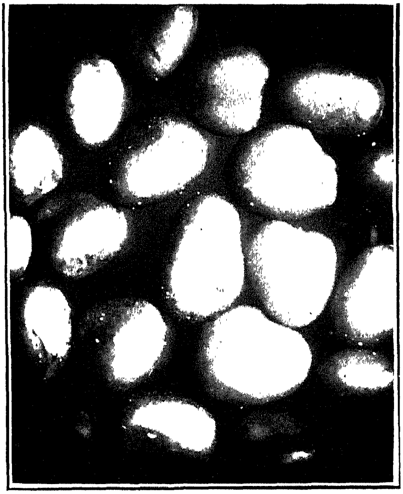

FIG. 3 —LADINO OR GIANT WHITE CLOVER. × 10.

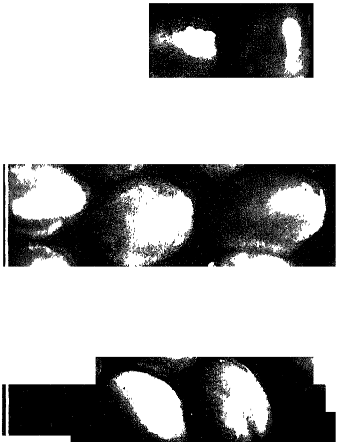

FIG. 4. —YELLOW SUCKLING CLOVER. × 10.

To face p. 1312

WILD WHITE CLOVER (*Continued*)—

Where the plant is abundant in old pastures, profitable crops of seed may be obtained by careful management. Some important points are here given. The herbage should be rather closely and evenly grazed by cattle and sheep until the end of May or middle of June, after which the field may be "closed" for seeding. The seed should not be allowed to become "dead ripe," otherwise loss will occur in harvesting, and the proportion of "hard seed" may be unduly increased. It is sufficiently ripe when, in the majority of cases, the flowers of the heads are reflexed and brown in colour, and the seed has assumed its first natural lemon-yellow colour and is fairly firm. A patchy crop, especially if very short, may have to be cut with the scythe. More regular crops may be cut with a grass mower set close to the ground. A piece of canvas attached to the bar of the mower and allowed to drag behind is useful for collecting the seed heads, which can be removed in heaps as required. The heads, with stalks and leaves, should be well air dried and afterwards placed in small stacks, care being taken to prevent any heating. After a few weeks in stack the seed may be thrashed out by a clover "huller," or by more modern seed extractors designed for this purpose. The "impurities" removed by screening usually include a high proportion of valuable seeds, *e.g.*, perennial rye grass, crested dogstail, etc.

Seed crops should not be taken from old pastures more frequently than every second or third year. In the intervening years the plant should be encouraged to spread by dressings of phosphatic fertilizers. Fairly close and even grazing, and also rolling in the early months of the year, are also beneficial.

Wild white clover seed may be sown on suitable clean land, and a crop of practically pure seed obtained in the second year. Such seed must be sold as "*once grown*" seed. The present evidence indicates that "once grown" seed is equal in value to that obtained from old pastures. It is possible, however, that if the process were repeated the persistent character might be reduced in the resultant plants.

The seed is at present chiefly grown on the Weald in Kent and on the Cotswolds in Gloucestershire, but its production is being extended in several other districts in the south, east, and north of England. The yield naturally varies considerably; from old pastures from 30 to 100 lbs. per acre is usual, while in the case of "once grown" seed twice that yield is not uncommon.

Certification of English Wild White Clover Seed Crops—The great *importance of genuineness* in the sale and use of this seed is now so generally recognized that steps have been taken recently to assist those engaged in its production and marketing. The Ministry of Agriculture in co-operation with the National Farmers' Union have organized a scheme for the inspection and certification of farmers' crops on payment of a fee to cover expenses. Growers who wish to have their crops inspected may make application before the middle of April through the local branch of the National Farmers' Union.

Inspections are arranged by the Ministry of Agriculture, and if

WILD WHITE CLOVER (*Continued*)—

satisfactory the field is registered as an "approved field" and the grower as an "approved grower." Seed is also taken from the field and submitted to a "growing-on test" by the Ministry. When a grower has harvested and cleaned the produce of an "approved field" he is supplied with an official certificate bearing a reference number which may be quoted in connexion with sales of seed which is the produce of the crop certified.

The Ministry issues certificates for two grades of seed: the "Grade A" certificate relates to crops from genuine old pastures, *i.e.*, those which have been under grass for ten years or more; while the "Grade B" certificate refers to crops of once-grown indigenous wild white clover, *i.e.*, once-grown from seed from genuine old pastures. Type samples of the seed of every certified crop must be deposited at the Official Seed Testing Station, Cambridge, and any purchaser of seed sold under a certificate number is entitled to send a sample to that Station for a growing-on test, at a nominal fee.

Ordinary White or Dutch Clover—The ordinary white or Dutch clover of commerce (*T. repens*, race *hollandicum*) appears to have been introduced into England from Holland in the seventeenth century. It is no doubt derived from the wild indigenous type, but has lost the high degree of persistence possessed by the wild form. Its stolons, leaves, and flower stalks are larger, its internodes are longer, and its habit of growth much "looser" than wild white. It fails, therefore, to grip the ground in the same way, and it does not form so dense a growth of foliage. It also flowers earlier than wild white, and the seeds may be distinguished as indicated above. (See Plate XXV, Fig. 1.)

For leys of one or two years, and for temporary grass generally, it may be used with advantage, as under favourable conditions it will last from three to five years or longer. At present its seed is much less expensive than wild white clover.

Lodi Clover, Ladino, or Giant White Clover (*T. repens*, race *giganteum*) (Plate XXV, Fig. 3)—This is a form which is grown under irrigation in northern Italy. Its stolons, leaves, etc., are much coarser even than the Dutch white, and its growth is of a loose and straggling character. It is less resistant to frosts than either Dutch or wild white, and in Britain is generally of less agricultural value than either. S. F. A.

WINDMILLS—These simple power units were in use for grinding corn at least as early as the twelfth century. Two types developed, one in which the sails rotated in a horizontal plane, and the other in which this rotation was in a vertical plane. The first type died out comparatively rapidly, as its efficiency was low, since only a quarter of the total sail area could be exposed to the wind at one time. Mills of the second type differ in the means adopted to bring the sails into the wind. One pattern which developed in Germany had the whole building made to swing round upon a central pole, another grew up in Holland in which the mill itself was of masonry, and only the roof and sail mechanism turned. During the last century a third type

WINDMILLS (*Continued*)—

has grown up in America, which consists of a circle of metal vanes placed on a high metal lattice tower. It is used for water pumping and also to some extent for grinding corn.

In mills of the Dutch pattern, and often in the German, the sail axle is set at an angle of about 15° to the horizontal to catch what is called "the dip of wind direction." The lower layers of a stream of air moving over the surface of the earth are continually checked by contact and internal friction, with the result that for these mills whose sails sweep within a short distance of the ground the wind, in gusts, acts as if it blew somewhat down on to them. This tilting is unnecessary in mills of the American type whose sails remain at a height in one air stream, and the advantage is doubtful in the case of those of the German type, as the sails must in any case be strong enough to withstand the strain of receiving the top of a gust before the bottom. In the Dutch form tilting is necessary in order that the sails may clear the masonry of the mill. The motion of the sail axle (*wind shaft*) is communicated to the machinery of the mill by a pair of crown bevels. The sails were originally brought into the wind (*veered*) by hand, but in 1750 Andrew Meikle introduced the auxiliary rotating fan at right angles to the sails, which rotates and brings the sails round whenever the wind blows from either side. This fitting is now almost universal. In high winds the sails, if of sailcloth spread on frames, have to be reefed for safety, but an automatic reefing sail consisting of wood slats so weighted as to give a little and allow the wind to pass through the sail in heavy gusts is now common.

In the American type of mill the sails are numerous and disposed round an annulus. They are usually of heavily galvanized iron. Veering is accomplished by a rudder at the back in a plane at right angles to the sails, and reefing is automatic, either by a subsidiary vane in the wind turning the rail ring oblique to the wind, or by a centrifugal governor lifting the weight which keeps the vanes themselves up to the wind. (For further particulars see report by F. S. Courtney, *Journ. Roy. Agric. Soc.*, lxiv., 174, 1903.)

A fourth pattern of mill has been made in England by Messrs. Warner of London which combines the Dutch and American types. It is a masonry mill of full size with tilted wind shaft, but the sails are of the annular variety on a ring some 80 ft. diameter. The idea is also applied to tower mills. The vanes are kept up to the wind by spiral springs.

The performance of windmills is affected very considerably both by design and by atmospheric conditions outside the control of the designer. Consider in the first place the matter of size. As the linear dimensions increase, the area of sweep of the sails increases as the square of the linear dimensions, and so the power is correspondingly augmented at the same wind velocity. On the other hand, the weight of material and cost goes up about as the cube of the linear dimensions; indeed, where it is a question of actually increasing the horse power by this means, the above is if anything an understatement, for two reasons. In the first place, if the sweep of the sails is doubled, the shafts con-

WINDMILLS (*Continued*)—

necting the sails to the hub of the wind-shaft (whips) must be more than four times as strong, since not only is the wind pressure multiplied by four, but the centre of pressure on any whip is carried out further from the hub; and secondly, the pressure variations over a single sail are greater, due to the greater range of velocity of movement across the wind. It would therefore appear that a number of small mills might be better than one large one, but it must be remembered, as C. A. C. Brown points out (*Encyc. Brit.*, 14th edit., "Windmills and Windpower"), that since the power costs nothing, a large inefficient wheel may be preferable to a small efficient one which costs more to manufacture. (See Oxford tests below.)

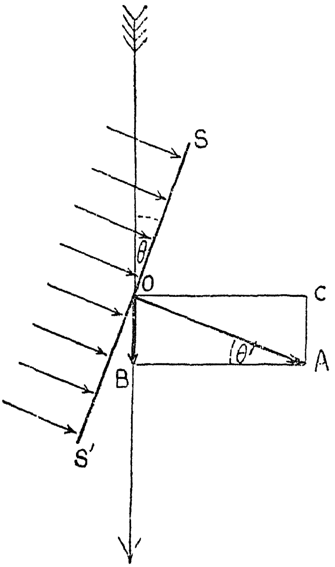

FIG. 41.

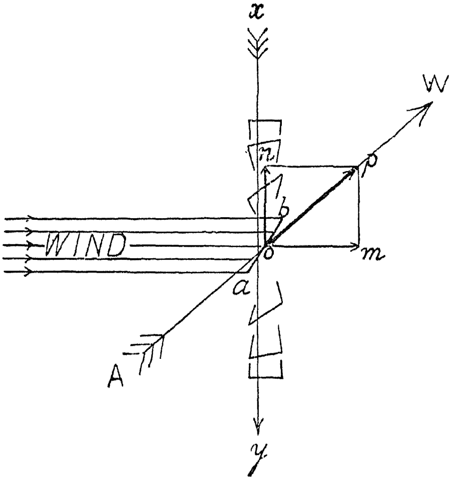

FIG. 42.

In order to understand, in however simple a way, the problems of sail design, it is necessary to go to some slight extent into the mathematical and physical principles involved. Let SS′ in Fig. 41 be a sail or vane, it is immaterial whether it be conceived as of the European or American pattern. Suppose it fixed on an axle in such a way that it can move only in the plane indicated by the large arrow, and let wind fall upon the face of the vane in the manner indicated by the small arrows. This wind will exert a force on the vane in the direction OA $=f$ (say). In accordance with the usual proceeding depending on the parallelogram of forces, this force can be imagined replaced by two others, OB, which causes the vane to move in the direction of the large arrow, and OC, which has no such action. OB, it will be noticed,

WINDMILLS (*Continued*)—

is very much less than f, the force acting at right angles to the vane, and clearly as the angle θ between the vane and the direction of rotation is lessened, OB becomes a smaller and smaller fraction of f. Stated in trigonometrical terms, calling OB the effective force e, we have:

$$e = f \sin \theta \ (\theta' = \theta).$$

Passing now to the magnitude of the force f. If the wind velocity in the direction of the small arrows in Fig. 41 were doubled, the force f would be four times as great, for the existence of the force is due to the vane as it were holding up the wind, and is therefore proportional to the kinetic energy of the wind, which varies as the square of the velocity. We may write for simplicity $f = \mathrm{K}v^2$, where v is the velocity of the wind and K is a constant depending upon the air density and other things. (See F. W. Lanchester, "Aerodynamics," London, 1907, p. 187, for further discussion of this.) The force f, and therefore the effective force e, then, varies as the square of the velocity.

In a windmill, however, the wind does not fall on the vane as shown by the small arrows in Fig. 41. Turning to Fig. 42, consider the vane ab moving downward as indicated by the arrow xy with a velocity $= u$, while the wind is blowing in the direction shown with a velocity $= v$. An observer situated on the near edge of the vane would, if there were no wind, and the mill were still rotating, experience a wind of velocity u in the direction yx. This velocity will have to be combined with the wind velocity v to give the apparent direction and velocity of the wind actually striking the vane. Velocity being a vector quantity, we may again apply the parallelogram construction, and if we make $om = v$ on some scale, and $on = u$ on the same scale, then op will represent on the same scale the speed of the wind striking the vane and its direction. Hence the vane will receive wind at a velocity $op = \sqrt{u^2 + v^2}$ in the direction indicated by the arrow AW. The question now remains—what force at right angles to ab will be exerted by a wind of velocity $\sqrt{u^2 + v^2}$ in the direction AW, making an angle $\mathrm{A}oa = \xi$ (say) with ab? Here elementary laws cease to hold, and for purposes of this article we shall do no more than state that this pressure is equal to

$$\mathrm{K}(u^2 + v^2)\frac{2 \sin \xi}{1 + \sin^2 \xi} = f.$$

The reader who wishes to follow this matter out more carefully will find the treatment of it by Lanchester (*loc. cit.*, pp. 200-214) of interest. One reason why the elementary laws do not apply is that the vane is continually moving from air which has been checked by it into air which has not been checked by it.

The effective pressure driving the vane, then, will be:

$$e = f \sin \theta = \mathrm{K}(u^2 + v^2)\frac{2 \sin \xi}{1 + \sin^2 \xi} \sin \theta.$$

WINDMILLS (*Continued*)—

It is clear from this that the effective force is zero when $\theta=0$ and also where $\xi=0$. Now ξ (see Fig. 42) depends on the ratio $\frac{u}{v}$, known as the *speed characteristic*, and for every value of this there will be a value of θ between 0 and $\cot^{-1}\frac{u}{v}$, which makes this effective force a *maximum*. Whence it follows that in mills of the European type, and in many of the American type, *i.e.*, those in which the sail length is more than a small part of the diameter, the angle θ will have to be varied along the length of the sail, since u of necessity varies, if maximum efficiency is to be attained, and it is for this reason that windmill sails are usually *warped*. In those of the European type the sails are usually set at an angle of about 18° to the weather near the hub of the wind shaft, decreasing to 7° at the outer extremity of the sail.

The speed characteristic being fixed for the sail tip in any mill, it is clear that u^2 in the above equation may be substituted in terms of v^2, so that $e \propto v^2$, and since the work done per unit time $\propto eu=ev\left(\frac{u}{v}\right)$, we have:

$$\text{Power}=\text{work per unit time} \propto ev \propto v^3.$$

Thus, the horse-power developed varies as the cube of the wind velocity.

Mills of the European type have normally a sail tip speed characteristic of between 2 and 3. In the American type there are three classes—low speed mills, speed characteristic 0·75 to 1, in which the sails are often unwarped, the velocity component in the plane of rotation being small; medium speed mills with a speed characteristic equal to that of European mills with, usually, warped vanes, and high speed mills with a speed characteristic between 3 and 6, with 2 or 4 vanes only, the tips being streamlined like an aeroplane propeller blade. Comparative tests of efficiency of these three types have been made by Sabuini (*Trans. Aer. Hydrodyn. Inst., Moscow*, 1926) with the following results:

	Best Efficiency.	*At* $\frac{u}{v}=$
Low speed	0·33	1·17
Medium speed	0·22	2·00
4-blade high speed	0·42	3·10
2-blade high speed	0·36	4·30

Owing to various aerodynamic considerations there is a theoretical maximum efficiency for windmills of 0·59, and it will be seen that the four-blade high speed wind wheel gives a good practical approach to this; but such wheels are handicapped by the possession of a very low starting torque.

An *approximate* estimate of the horse-power of a wheel mill may be obtained from the formula $\text{H.P.}=0{\cdot}00000226\ AV^3$, where A is the wheel area in square feet, and V the wind velocity in miles per hour, but

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at low wind velocities this will give a considerable overestimate. Tests made at the Wisconsin Agricultural Experiment Station (*Bull.* 82, 1898) show that at wind velocities of less than about 13 miles per hour the efficient horse-power of a mill falls off rather as the fourth power than the cube of the velocity, and this may well account to a large extent for the concentration of windmills in Northern Europe in low-lying regions not far from the sea coast, such as East Anglia, the Fylde, Holland, North Germany, Denmark, and Southern Sweden. In these parts average wind velocities range around 12 to 15 miles per hour, while in inland regions they are not more than about half these figures.

The wind velocity having such a marked effect on the performance of these mills, it is but natural that this should be greatly affected by the height of the tower, since the wind velocity is always greater at a height. Stevenson (*Jour. Scot. Met. Soc.*, 1881) computes that if v is the wind velocity at 50 ft., then V_h, the velocity at height h ft., is given by the formula

$$V_h = \frac{v(h+72)}{122}$$

Whence it follows that a wheel at 100 ft. would be more than two and a half times as useful as one at 50 ft. In any case the vanes should always be placed several feet higher than any trees or other obstructions within a quarter of a mile of the mill.

Apart from wind velocity and factors affecting this, the performance of windmills is dependent to some extent on barometric height, and therefore on altitude above sea-level, on the temperature of the air, and therefore on latitude and season of the year, and on the humidity of the air. All these affect the density of the air, and so change the constant K in the expression for wind pressure. The humidity effect is theoretically twofold according as the water is present as vapour or minute water particles. As vapour it reduces the density, and therefore *ceteris paribus* the pressure; on the other hand, if present as minute water particles not large enough to be deposited on the vanes, it may increase the effective mean density and so augment the pressure.

Windmills, it will be clear, are only suitable for performing such types of work as can be done at any time when the wind serves, unless means of storing the energy and using it as required are available. They are commonly used for pumping water to suitable reservoirs, grinding grain, chopping straw and fodder, etc., and have been employed with fairly satisfactory results in America to the irrigation of small areas. Of late years attention has been focussed upon them as possible sources of power to drive dynamos for small lighting plants on farms. In this regard undoubtedly the greatest drawback is the high cost of the necessary bank of accumulators and the difficulty of securing a steady charging current. This is usually obtained by using a constant voltage machine with automatic switching in and out of the cell circuit as the machine rises above or falls below the necessary number of revolutions. In Burne's pattern (see *J.R.A.S.E.*, lxxxviii.,

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333, 1924), special arrangements are made to charge many or few cells at a time with a steady charging current, avoiding disintegration of plates or abnormal sulphating of positives. It can also be run in lighting hours without injury to the lamps.

High speed mills are usually chosen for generation of current as they are more efficient, require less gearing, have a smaller surface area, and are therefore less subject to gale damage, and are more easily erected. The problems in connection with their use for this purpose are discussed by C. A. C. Brown, art. "Windmills and Windpower," *Encycl. Brit.*, 14th edit.

Efficiency tests at Oxford with such mills showed that current could be generated at a cost of 12·7 pence per kw. hour by a machine giving 316 kw. hours annually, while with a machine giving 7,640 kw. hours annually the cost fell to 4·1 per pence kw. hour. T. D.

WINTER HARDINESS AND DROUGHT RESISTANCE—Introduction— The resistance of plants to such unfavourable climatic conditions as frost and drought, in addition to being one of the most important problems of applied plant physiology, also attracts the lively interest of agriculturists and horticulturists.

It happens very often in agricultural regions, particularly under conditions of continental climate, that a dry summer destroys all the efforts of the farmer, or a severe winter provokes a considerable damage not only to fruit trees, but also to winter crops. The only means of fighting successfully against these fatalities is an exhaustive study of the causes of the death of plants from frost and drought, and of the factors on which the different degrees of their resistance depend. This study, besides being of very practical interest, is also important from a theoretical point of view, as it assists in the approach to a fuller understanding of some physico-chemical properties of protoplasm.

The Cause of the Death of Plants from Freezing and from Drying— From the theoretical point of view both questions—winter hardiness and drought resistance—have much in common, as in both cases we have to deal with the capacity of the protoplasm to withstand the injury induced by strong dehydration. In fact, the action of frost upon the plant tissues consists mainly in the accumulation in the intercellular spaces, or, sometimes, in the cells themselves, of ice crystals, which are formed from the water abstracted from the protoplasm. Besides this, during a frost period, a gradual general desiccation of the plant takes place, and as its overground organs continue to transpire, it cannot restore the water so lost from the frozen soil.

First of all, let us consider the changes that occur in the cells of plants during the loss of water. The living protoplasm presents a colloidal system which for its normal function requires to be in a state of sufficient imbibition. Through loss of water by the cell, the concentration of the cell sap increases, and in its turn the cell sap draws water from the protoplasm, its degree of imbibition decreases, and all the life functions, particularly growth and assimilation, dim-

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inish, and finally stop entirely (H. Walter, "Plasmaquellung und Wachstum," *Zeitschr. f. Bot.*, xvi., 1924).

Very few plants are able to endure total desiccation such as we know it in seeds. These are mainly lower plants—lichens, mosses, certain ferns, and a very few desert plants (Ivan Vasiliev, "Anabiose bei *Carex* physodes," *Berichte Bot. Gesell.*, xlviii., 153-155, 1930). In the great majority of plants too high a loss of water provokes the death of the cells, and it is important to point out that the dying off begins when only half, or slightly more, of the total water of the cell is lost. When this happens the central vacuole does not yet disappear, but only decreases its volume.

This dying off of the protoplasm by such a comparatively insignificant dehydration is a result of the following processes:

With the loss of water by the cell the volume of its central vacuole diminishes; correspondingly, the plasma sac that covers it contracts, as well as the cell membrane, which loses its natural turgid state; externally such a state of the cells is manifested by wilting.

If the process of wilting has not proceeded too far, the plant recovers again after watering, but excessive wilting proves to be noxious or even fatal. The cause of this lies in the fact that the cell membrane, being comparatively inelastic, is not capable, with a further loss of water, of following the contraction of the protoplasm. A deformation and a rupture of the protoplasm thus occurs, as one part of it remains in contact with the membrane and the other follows the contracting vacuole (Iljin, "Ueber die Austrocknungsfähigkeit des lebenden Protoplasmas," *Jahrb. f. wiss. Bot.*, lxvi., 947-964, 1927). That is why such cells in which the vacuole has a greater volume, thus creating conditions of a greater deformation of the plasma, die more readily from dehydration. On the other hand, embryonic tissues that are entirely filled with protoplasm are notably more resistant to desiccation; cells that are filled with storage substances such as starch or oil are also much more enduring.

Another peculiarity of the cells that conditions the results of the wilting must be the chemical property of the protoplasm. Certain colloidal substances undergo irreversible changes with dehydration, thereby losing the capacity to swell, whilst others, on the contrary, re-absorb water even after complete desiccation. The composition of the protoplasm of the plants may approach one or the other type, and correspondingly, the cells will be more or less capable of tolerating dehydration.

The phenomena which take place during freezing of plants are very similar to those that play a rôle in desiccation. Under the influence of frost, crystals of ice are formed on the surfaces of the cell walls in the intercellular spaces, the water from the cells is drawn to these centres of crystallization, the volume of the vacuole contracts, the cell sap becomes more concentrated, the protoplasm dehydrated, and the cell wall pressed in. Finally, a deformation of the cell and the death of the protoplasm takes place, just as with desiccation from drought. There is this difference, however, that with freezing, the

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water from the cell remains in the intercellular spaces and does not disperse into the surrounding atmosphere. Thus, the frozen parts of the plants become translucent, as the air from the intercellulars is replaced by ice and they prove to be wilted only after thawing. But if the cells remain alive, the water is re-absorbed and the normal turgor returns gradually. If, however, the tissue is killed by frost, it loses very easily the last remaining quantity of water, and dries out.

Whether the cells will remain alive or not after freezing or desiccation depends on several conditions It may depend on the physico-chemical peculiarities of the colloids of the protoplasm, whether they have the capacity to restore their original structure and their imbibition or not. But it may also depend on the quantity of water abstracted from the cells and transformed into ice.

Let us discuss this last case: The quantity of ice formed by a given solution on freezing depends on two factors: the temperature to which the solution is cooled, and its concentration. As we have just mentioned, on freezing a solution, pure ice is formed and the solution itself becomes more concentrated. For the moment, the water, which at a given temperature is turned into ice, may be termed free water, and that which remains in a liquid state, in form of a solution, water osmotically bound; then we can say that in solutions of different concentrations, but cooled to the same temperature, the quantity of the bound water is the greater the higher the concentration of the solution. For one and the same solution, cooled to different temperatures, the quantity of water that remains in a bound state will be smaller the lower the temperature. It was shown long ago (Maximov, "Experimentelle und kritische Untersuchungen über das Gefrieren und Erfrieren der Pflanzen," *Jahrb. f. wiss. Bot.*, liii., 327-420, 1914) that, assuming all other conditions similar, the results of freezing depend mainly on the quantity of the ice formed in the plant tissue. This makes comprehensible the significance of the raising of the concentration of the cell sap for the frost resistance of plants (Chandler, "The Killing of Plant Tissue by Low Temperature," *Mo. Agric. Expt. Stat.*, *Res. Bull.*, No. 8, 1913).

Another factor of frost resistance and resistance to desiccation is the chemical composition, and the physico-chemical capacities of the colloids that form the protoplasm. If these colloids can restore their original structure after a very strong freezing, then the plant will survive very low temperatures without damage.

A known example of an extremely resistant plant is the *Cochlearia fenestrata* which has been studied by the expedition of Nordenskjöld on the New Siberia Islands. This plant underwent a severe frost at the commencement of blooming, and survived a long and extremely severe winter, during which it was frozen completely. With the return of warm weather in spring it started its vegetation again from the phase of development in which the winter had met it. An opposite example is the potato, which succumbs to very little frost, and when only a quite insignificant part of its water is transferred into ice.

The causes which condition different relations of the protoplasm

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to frost in different plants are as yet not quite clear. Undoubtedly, the differences in the composition of the main colloids of the plasma must be of primary significance. Besides this, a number of workers have ascertained that the accumulation of sugars in the cells (Lidforss, "Die wintergrüne Flora," *Lunds Univers. Arskrift,* N.F. 2, Afd. 2, N. 13, 1907) favours an increased resistance of the protoplasm. The accumulation of amino acids, and, in general, the change of complex nitrogen substances of the protoplasm into more simple forms is also favourable to this increase (Schaffnit, "Studien über den Einfluss niederer Temperaturen auf die pflanzliche Zelle," *Mitt. d. K. Wilhelms-Inst. fur Landw. in Bromberg,* iii., 93-144, 1910). Evidently it is a specific protective action of these substances which prevents the denaturation of the colloids of the protoplasm by freezing. This protective action of sugars is easily observed *in vitro* in freezing protein solutions pressed out of plants (Lidforss, *loc. cit.*).

Winter Hardiness—(*a*) *Winter Cereals and Other Crops*—The phenomenon of winter killing is very often observed in winter crops. In agricultural countries, according to statistical data, the annual loss of all crops during the winter is 10 per cent.; in exceptionally unfavourable years it may reach 20 per cent. or more. It is easy to understand, consequently, that most of the investigations on winter hardiness are carried out with winter crops, mainly with wheat.

It has long been known that different varieties of winter wheat differ very much in their resistance to frost. Thus, the very productive English varieties of wheat of the Square Head type, that survives very well in west Europe, where the winters are mild, are not suitable for the continental climate of east Europe, where the winters are much severer. It is, therefore, one of the most important problems of the breeding institutions in these countries to select and breed the most frost-resistant varieties. Such work was conducted in Sweden for many years by Åkerman, at the Plant Breeding Station at Svalöf; in the United Soviet States Republic by the Department of Variety Tests of the Institute of Applied Botany, under the direction of Professor Talanov; in the United States of America mainly at the experimental stations in Kansas and Minnesota; and in Germany, at Halle, by Professor Römer. This work, which was verified by repeated trials under field conditions, formed the basis of a classification of the main varieties of winter wheat according to their winter hardiness; moreover, a number of new varieties of outstanding frost resistance were obtained, as, for instance, the American variety Minhardi, the Saratov's variety, Lutescens No. 329, and the Swedish variety Sammet.

Field experiments, however, prove to be very slow, as frosts are not of equal intensity every year; at the same time they are not quite reliable, as in the fields many other unfavourable factors, such as damping off, fungous infection, injury caused by animals, and so on, play their part during the winter. The necessity of substituting more rapid and reliable tests under laboratory conditions for field tests was soon realized. The simplest and most reliable method of selecting more

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resistant varieties is to freeze them at quite definite temperatures in special chambers cooled by means of refrigerating machines.

Åkerman, at Svalöf, was the first to apply this method, although his cooling chamber was very primitive. At the present time we already have a fairly large number of much better refrigerating equipments in Europe, and in the United States of America, built especially for the study of the frost resistance of winter crops. The methods used for these tests are comparatively simple. They necessitate the possibility of maintaining the temperature in the refrigerating chambers at a constant, precise level; a difference of even 1° can provoke a significant error in the comparison of different varieties. For this purpose the refrigerating chambers must be supplied with good working thermo-regulators. Again, after thawing the plants it is necessary to make a record of the injury, either by means of direct observation or by separating the dead parts from those surviving, and determining the percentage of survival in data of the dry weight (see a detailed description of the methods of Tumanov and Borodin, "Untersuchungen über die Kälteresistenz von Winterkulturen," *Phytopath. Zeitschr.*, i., 575, 1930).

The method of direct freezing, although simple in its conception, requires a very expensive equipment, available only to large experimental stations. It was necessary in consequence to find other means of determining frost resistance that could be applied on a large scale in the practice of the plant breeders, and of studying in detail those physiological peculiarities that make the difference between resistant and susceptible varieties. Of all these peculiarities the best studied are the differences in soluble carbohydrate content. The experiments carried out by Åkerman ("Studien über den Kältetod und die Kälteresistenz der Pflanzen," Lund, 1927) for many years have shown a fairly close correlation between resistance of the studied wheat varieties and their sugar content, in cold seasons of the year. These data were confirmed later by a number of other workers (Newton and Martin, "The Nature and Practical Measurement of Frost Resistance in Winter Wheat," *Univ. of Alberta, Research Bull.*, No. 1, 1924; "Comparative Studies of Winter Hardiness in Wheat," *J. Agric. Res.*, xxxv., 493-535, 1927), and the causal connexion between sugar content and resistance can be acknowledged as well-established. The determination of sugars in young plants of winter wheats gives, therefore, a fairly precise idea of their comparative frost resistance. It must be borne in mind, however, that the plants are taken from the field at the beginning of the winter and that varieties can be compared only in the limits of one genus. Varieties of different genera cannot be compared, as for instance wheat with rye, or barley, for the differences in resistance of different genera depend not only on the sugar content, but also on the chemical peculiarities of the plasma colloids.

As the sugars constitute the main part of the dry substance in the sap of the plants, one may substitute their minute determination by the determination of the total amount of the dry substances in the

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sap. For this purpose the refractometer is very useful, as it gives very rapidly, although not quite exactly, determinations of the percentage of the dry weight in the sap, when only a drop of it is used (H. Lueg, "Die Bedeutung verschiedener Untersuchungsmethoden zur Bestimmung der relativen Winterfestigkeit," *Wissensch. Archiv. f. Landw.*, i., 726, 1929; J. Tumanov, "Ungenügende Wasserversorgung und das Welken der Pflanzen als Mittel zur Erhöhung ihrer Dürreresistenz," *Planta*, iii., 391-480, 1927).

Another physiological characteristic by which one can determine the frost resistance of plants is the relative quantity of bound water, as we have already mentioned above. This quantity can be determined with help of a dilatometer (G. Bouyoucos, "Measurements of the Inactive or Unfree Water in the Soil," *J. Agric. Res.*, viii., 195-217, 1917). The investigations of Lebedincev ("Untersuchungen über die wassenbindende Kraft der Pflanzen," *Protoplasma*, x., 53-81, 1930) have shown a pretty good correlation between the relative quantity of bound water and frost resistance, and this method can therefore be applied for the indirect determination of frost resistance of different varieties, within the limits of one genus.

Such are the main indirect methods for determining the frost resistance of varieties of winter plants without applying slow field tests. The work with seventy-two varieties of winter cereals carried out in the author's laboratory has shown that each of these methods shows some divergence with the direct method of freezing in the cooling chambers, but that based on average data quite reliable results are obtained.

It is very necessary for the successful determination of comparative frost resistance, with the direct as well as with the indirect methods, to have in mind one important condition, namely, the plants must be similarly prepared for the experiment, the previous conditions of their cultivation, especially temperature and light, being strictly identical. The fact is that frost resistance is never constant, but changes within wide limits with the degree of hardening.

Hardening—The phenomenon of hardening was discovered long ago. It is a hundred years since Göppert ("Ueber die Wärme-Entwickelung in den Pflanzen, deren Gefrieren und die Schutzmittel gegen dasselbe," Breslau, 1830) observed that winter cereals grown in a greenhouse succumb at temperatures which do not in the least injure plants growing in fields. This phenomenon of hardening has been studied in details only in recent times, mostly by American and Russian authors (R. Harvey, "Hardening Process in Plants," *J. Agric. Res.*, xv., 83-112, 1918; J. Rosa, "Investigation in the Hardening Process in Vegetable Plants," *Miss. Agric. Expt. Stat. Research Bull.* 48, 1921; Lebedincev, *loc. cit.*; J. Tumanov, "Untersuchungen über das Abhärten der Pflanzen gegen Frost," *Phytopathol. Zeitsch.*, 1931, in press). By hardening we understand an increase of the resistance of plants induced by the influence of external factors. Among these, the influence of a lowered temperature has received the most attention. Keeping plants at temperatures from +5° C. to 0° C., and a little

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lower, considerably raises their resistance; on the contrary, their transfer to a temperature above +10° C. destroys the hardening which was previously acquired very rapidly. The hardening increases rapidly at the beginning, a high degree of hardiness being acquired on the first day; on the next day it rises little. Just the same, when plants are transferred into the warmth, the hardening is very rapidly lost. (See Refrigeration.)

The recent observations of Harvey ("Time and Temperature Factors in Hardening Plants," *Amer. J. Bot.*, xvii., 212-217, 1930), that the hardening proceeds well even in the case of a plant remaining at a lowered temperature only a part of the day, being the rest of the time at a higher one, are very interesting. This accounts for the fact that when the temperature in the day hours rises fairly high and falls to 0° C. or even lower in the night, the plants acquire a high degree of frost resistance that allows them to survive the spring morning frosts.

Among the changes that take place during hardening, first of all an accumulation of soluble carbohydrates that proceeds parallel with the dissolution of the starch reserves and of other polysaccharides was observed, then there is an increase of amino acid content that also takes place on account of more complicated nitrogen compounds. Both processes result in an increase of the quantity of bound water and in a decrease of the free water. Parallel to this, a general decrease of water content in the plant tissues take place, as the decrease in temperature retains more the absorption of water than its loss. All this together, as we already have mentioned, must greatly increase the frost resistance, and in fact it does. Another factor important in hardening, especially winter cereals, is the light. In contrast to biennial and perennial herbaceous plants, as well as to woody ones, the winter cereals do not accumulate either starch or other polysaccharides, and the accumulation of the soluble carbohydrates that are necessary for resistance is only a result of the photosynthesis. Therefore, a long period of darkness, although at a low temperature, does not increase, but, on the contrary, decreases frost resistance (Tumanov, 1931, *loc. cit.*).

As a result of the reciprocal action of all these factors we see at the beginning of the winter, when the snow layer that covers the plants is not yet thick, and photosynthesis is not stopped by low temperature, that resistance increases gradually, and normally reaches its maximum before January.

But after the reserves are spent the leaves of the cereals decrease their resistance and one by one die. Before spring, very often only the underground part—the tillering node—remains alive, and it begins growth when the warm weather comes. However, at the time of disappearance of the last snow this part of the plant, although being in general the most resistant, also becomes very weak, and can succumb very easily on the return of frosts. Thus, for winter crops, spring may be more destructive than winter itself.

In addition to the direct influence of frosts the winter cereals may

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be subjected during the winter to other unfavourable conditions; the most frequent of these is damping off. When snow falls on the soil that is not yet frozen the plants are in conditions of comparatively high temperature, deficiency of air, and full darkness under a thick layer of snow. Thereby they lose their reserves in the process of respiration, and finally become so weak from exhaustion and lack of air that they are easily attacked by different fungi and other injuries.

As damping off is conditioned by quite different causes than freezing to death, it is quite natural that resistance to damping off does not coincide with the frost resistance. Therefore the usual field tests for frost resistance, when one takes account of the number of plants that survive per unit of area, do not disclose all the causes which provoked the injury observed after winter. Thus, one can explain the fact that in different localities different varieties prove to be the most winter hardy.

There is one other cause that conditions winter killing, especially in very wet soils, that is, the formation of a layer of ice crystals at a certain depth below the soil surface. This ice layer, increasing in thickness during strong frosts, raises the layer of soil above, together with the plants in it, and tears the roots that grow in the deeper part of the soil. Thus, varieties with strong roots, which stand well against tearing, or can easily replace the injured roots by new ones, prove to be the most resistant to the so-called heaving. This form of winter resistance has certainly nothing to do with frost resistance in the true meaning of the word.

(*b*) *Trees and Shrubs*—Trees and shrubs over-winter in quite different conditions to herbaceous plants; the latter are protected from extreme temperatures and from desiccation by winter winds by a snow cover, and their most important organs, such as the growing points and storage tissues, are, in addition, covered by a more or less considerable layer of soil. The branches of trees and shrubs, on the other hand, are deprived of such a protection, and subjected to all the trials of the winter.

The temperatures to which the branches of woody plants are subjected in winter are considerably lower than those which we have discussed for the winter cereals, and we find, therefore, that they are equipped with more effective means of protection. All the living aerial parts of the trees, especially the buds and thinner twigs, lose the greater part of their water early in winter; instead of the 70 to 80 per cent. there remains only 30 to 40 per cent., nearly all of which is either osmotically or colloidally bound. The freezing point of these parts of the plant is, therefore, considerably lowered, and ice formation begins only at temperatures below −10° C. and even −15° C. Correspondingly to this, frost resistance increases considerably.

Such a high resistance of woody plants is observed only in the winter months; in the summer it decreases very much and they are injured at temperatures of −5° C. to −8° C. Here we meet again with hardening, similar to that which is discussed in con-

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nexion with field crops. Especially pronounced in trees is the increase of the quantity of bound water in winter (Meyer, ' Seasonal Variations in the Physical and Chemical Properties of the Leaves of the Pitch Pine," *Amer. J. Bot.*, xv., 449-472, 1928). There is also a conversion of starch into sugar (Fischer, " Beiträge zur Physiologie der Holzgewächse," *Jahrb. f. wiss. Bot.*, xxii., 73, 1891), and, by some species, an accumulation of considerable amounts of oil in the cells. According to the recent data of Iljin (*loc. cit.*), this must also raise frost resistance.

Usually, the increase in resistance towards autumn is concomitant with "ripening" of the twigs; and twigs that have not "ripened" are easily injured by frost. The "ripening" consists mainly in checking the processes of growth; in the ripened parts there remain either embryonal cells (especially in buds) or cells that have completely finished their growth and are filled with reserves. It is just such cells that are the most resistant, and, on the contrary, cells that are in a state of a rapid growth prove to be the least resistant.

Different varieties of woody plants exhibit quite different winter hardiness, a fact well known to horticulturists, who distinguish for every species hardy and tender varieties. The internal causes of these differences are much less clear than in field crops. Most of the methods applied to show the differences in frost resistance of field crops, as, for instance, differences in sugar content or in the quantity of bound water, are not always applicable to woody plants (Steinmetz, "Winter Hardiness in Alfalfa Varieties," *Univ. of Minnes. Agric. Expt. Stat., Techn. Bull.*, No. 38, 1926). Only Lott (" Correlation of Chemical Composition with Hardiness in Brambles," *Univ. Missouri Agric. Expt. Stat., Research Bull.*, No. 95, 1926) succeeded in getting favourable results for different varieties of brambles. In recent times Dunn and Bakke (" Adsorption as a Means of determining Hardiness," *Plant Physiol.*, i., 165-178, 1926) endeavoured to find a correspondence between the frost resistance of fruit trees and the quantity of hydrophilous colloids in their twigs. These are measured by determining the capacity of the dried and powdered twigs to absorb aniline dyes. The results obtained were, however, not quite satisfactory.

Different parts of the twig, as well as of the whole tree, show different frost resistance, and we usually find after cold winters that not the entire trees, but only separate parts of them are injured. Especially sensitive is the young wood of the internodes; the buds and cambium zone, built of embryonic cells, are more resistant. The old trunks of the trees are also more resistant, probably as a result of a certain protection by a thick layer of the bark. The wood of the base of the trunk of the young trees is very sensitive, but usually these more sensitive parts of the plant are not injured entirely, but only in certain parts. Such injuries are later, so to speak, cured by the activity of the cambium, that forms new layers of healthy tissues above the dead wood. However, these dead parts very often are attacked by different fungi, which cause heavy injuries and even a

WINTER HARDINESS AND DROUGHT RESISTANCE (*Continued*)—

dying off of entire twigs and whole trees, sometimes after an interlude of several years.

Trees very often suffer in winter not only from the direct action of frost, but also from extensive desiccation. This is especially obvious in mountains, at the upper boundary of the forest, and at the polar boundary of woody vegetation. Here the desiccating winds cause the death of most of the young twigs, and the trees acquire a deformed, monstrous appearance. The main protection against desiccating action is the layer of cork that covers even the youngest twigs, and also the bud scales which protect the growth apexes. The autumn ripening of twigs is externally manifested by formation of a cork layer that covers them to the extreme tips.

Different varieties of woody plants possess quite different capacities to withstand winter desiccation, depending on the thickness and density of the construction of the cork, and also on the number and size of the lenticelles. Amongst the weakest parts are the so-called "leaf scars," the points where a fallen leaf has been attached—parts covered by a thin layer of cork only. According to recent investigations more water is lost through these scars than from the whole surface of the twig (Gordiagin, "Ueber die winterliche Transpiration einiger Holzgewächse," *Beihefte z. Bot. Centr.*, Abb. I., xlvi., 93-118, 1929). The distribution of woody plants on the Eurasian continent from the west to the east, from the more humid climate to the drier one, is explainable in a great degree by their relative capacity to reduce the water loss by their wintering organs. Evergreen trees, which retain a large transpiring surface throughout the winter, are adapted to a warmer and more humid climate.

The conifers are an exception, as their leaves, thanks to certain anatomical peculiarities, lose very little water, even less than twigs of deciduous trees covered with cork.

It is very often difficult to decide in practice what has caused the death of the tree—desiccation or freezing to death. And this certainly makes the study of frost resistance in woody plants extremely difficult. In recent times some authors (Walter, "Die osmotischen Werte und die Kälteschäden," *Ber. Botan. Gesell.*, xlvii., 338-348, 1929) go so far as to deny in general the significance of freezing in the case of trees, and they consider desiccation to be the only cause of the winter damage. Such a point of view, however, is too one-sided.

Drought Resistance—The influence of drought upon the plant is considerably more complicated than that of frost, and the means of reaction on the part of the plant appear to be much more various. Therefore, the conception of drought resistance proves to be a more complicated one, and at the same time less elaborated. Until recent times the dominating view was that the main peculiarity distinguishing plants from dry habitats, the so-called xerophytes, which constantly endure a deficiency in water, is their capacity to reduce the loss of water into the surrounding atmosphere to a minimum. The investigations of recent years (Maximov, "Physiologisch-ökologische

WINTER HARDINESS AND DROUGHT RESISTANCE (*Continued*)—

Untersuchungen über die Dürreresistenz der Xerophyten," *Jahrb. f. wiss. Bot.*, lxii., 128-144, 1923; *idem.*, "The Plant in Relation to Water," London, 1929; *idem.*, "Internal Factors of Frost and Drought Resistance in Plants," *Protoplasma*, vii., 259-291, 1929; B. Huber, "Die Beurteilung des Wasserhaushaltes der Pflanzen," *Jahrb. f. wiss. Bot.*, lxiv., 1-120, 1929; H. Walter, "Die Anpassungen der Pflanzen an Wassermangel," Freising, München, 1926) have, however, confirmed with full precision that this peculiarity is far from being characteristic of all the xerophytes, and that, on the contrary, many of them transpire very much, at least in periods when they are well supplied with water. Generally speaking, the group of xerophytes is a very various one. We can distinguish among them plants that have a well-developed root system reaching to a great depth and drawing upon the underground waters, which they expend quite wastefully.

On the other hand, there are plants of the type of the cacti, that accumulate water in their fleshy stems and then spend it very scantily. In the deserts we find ephemeral plants that develop with an unusual rapidity which allows them to fruit before the dry and hot period of the year arrives; also plants capable of retaining their vitality even during the hottest time, thanks to their capacity of enduring a high degree of dehydration of their tissues, and capable in a half-wilted state of reducing their loss of water to a minimum.

Such a diversity of types makes it almost impossible to find any characteristics which are general for the whole group of xerophytes. Therefore, the explanation of the anatomical and physiological peculiarities distinguishing the drought-resistant cultivated plants from susceptible ones cannot be found in the analogy with the wild xerophytes. For this purpose another way proved to be more convenient, namely, the study of the changes called out in the plants by the changes of external and internal conditions which raise the loss of water or check its supply.

Quite definite differences are found when different specimens of one and the same variety, grown in a drier and in a more humid atmosphere, in a drier soil and in a moister one, in bright light and in weakened light, or, finally, in conditions of a constant water supply and in conditions of periodical wilting, are compared. In all cases when the plant suffers from a deficiency of water the following changes in the morphological and anatomical structure are found: the general size of the leaf surface reduces; the net of veins of the leaf becomes denser; the quantity of conductive elements in them rises; all the cells of the plant, including the stomata, diminish in size, but the number of the latter per unit of leaf area rises; when the leaf possesses hairs, their number rises; the cuticle that covers the leaf and stem becomes thicker. The sum of the morphologo-anatomical changes can be characterized, in short, as the raising of xeromorphism. This is accompanied by certain physiological changes. The works of a number of authors (see the literature in my book "Plants in Relation to Water") have shown that plants which, under influence of external conditions, acquire a more xeromorphic structure, exhibit concurrently a higher

WINTER HARDINESS AND DROUGHT RESISTANCE (*Continued*)—

sap concentration, a higher assimilation, and a higher transpiration when the stomata are open, *i.e.*, in conditions of sufficient water supply. But when, as a result of water deficiency, the stomata close and the thick cuticle protects the leaf, a reverse situation, *i.e.*, a decrease of assimilation and of transpiration, is observed. And the most important point is that the plants acquire the capacity of enduring permanent wilting, *i.e.*, a stronger dehydration of their tissues without harm.

This last property—the capacity of enduring permanent wilting without harm—is the most important physiological peculiarity of the drought-resistant plants. This capacity together with other peculiarities gives them a number of important advantages over less drought-resistant plants in conditions of a dry climate. As they do not suffer from dehydration of their tissues, they can keep their stomata open longer, and continue assimilation, when susceptible plants close them, thereby reducing assimilation and decreasing their yield in consequence. A high transpiration assists in reducing the temperature, which is also of great importance during drought. This transpiration continues uninterrupted thanks to a dense net of veins. And at the same time when the water is already exhausted and the plant begins to wilt the thick cuticle assists in prolonging the retention of the last reserves of water necessary for the life of plants.

From the practical point of view it is very important to ascertain how the more resistant varieties of cultivated plants may be distinguished. This is quite indispensable for breeding varieties suitable for dry regions. One of the main peculiarities of a xeromorphic structure is, as we already have seen, the decrease in the size of all the cells of the plant. Therefore in selecting for drought resistance one can take account of the size of cells—the smaller the cells are (other things being equal), the higher the drought resistance. The significance of the size of the cells is especially advanced by the Russian breeder Kolkunov and his school (Kolkunov, "Contributions to the Problem of breeding Drought-Resistant Crop Plants," Kiev (Russian), 1905; *idem.*, "Einige Ergebnisse der Untersuchungen über Dürrewiderstandsfähigkeit bei Kulturpflanzen," *Zeitschr. f. Pflanzenzucht.*, x., 297-310, 1925).

But size alone does not decide the question, as drought resistance may depend not only on resistance, but also on other factors. Therefore, to determine the drought resistance by wilting, a method given by Tumanov is more reliable. This method consists of cultivating the plants in porous pots filled with soil, and in suspending watering at a certain stage of development. This brings the soil to a gradual drying, and the plants thereby wilt. After sufficiently long and strong wilting the plants are watered again, and from the degree of the injury caused by wilting one judges the degree of their drought resistance.

As the raising of drought resistance is connected with an increase in the concentration of the cell sap, a decrease in size of the cells, as well as with a decrease of leaf surface, drought-resistant varieties

WINTER HARDINESS AND DROUGHT RESISTANCE (*Continued*)—
are usually not very productive; consequently, they are only cultivated in dry regions. In more humid regions, on the other hand, it is more practical to cultivate less resistant but more productive varieties.

N. M.

WOOL—Wool is the covering fibre usually present on the sheep (*Ovis aries*). Sometimes this covering fibre is hair only, sometimes hair and wool, sometimes a fibre of a nondescript nature—neither hair nor wool, but to-day most frequently it is true wool. Even the true wool fibres, however, vary in accordance with the sheep which produce them, and it will be well, in the first place, briefly to review the types of sheep and their respective histories.

Historical—The histories of the domesticated sheep, from which practically the whole of the world's wool supply is derived, seem to follow the histories of migrations of people from the central plains of Asia, or perhaps more particularly from the eastern shores of the Mediterranean, to the far-away lands of western Europe and South Africa. Thus, the typical British sheep shows evidence of having travelled with the Nordic peoples across the plains of Central Europe. Flocks of these sheep spread out and make the best use of pasturage; snow does not trouble them—they scratch it away from the herbage and feed without difficulty; and dangers seem to be faced rather than avoided. On the other hand, the typical Merino sheep shows evidence of an intensive domestication, is essentially gregarious, and is helpless in a snow storm—never attempting to scratch away the snow from the herbage. In Canada, however, it is noticed that the merinos will follow a snow plough while the British sheep will not do so! These traits of the Merino sheep are all referable to the Mediterranean and, more particularly, the Spanish origin. Probably the Afrikander sheep—a species of broad-tailed sheep—is linked up with the migrations of the Basuto people who were working down into South Africa from the north at the same time that Dutch and British settlers were working up northward from the south. Possibly the black-headed Persian sheep has followed Hindus and Asiatic migrations into South Africa.

Professor Cossar Ewart, some few years ago, worked out the origin of our domestic sheep, and explained in an interesting manner the origin of the wool coat of the domestic sheep, as distinct from the hair and wool coat which the wild sheep carries. Thus, it would appear that the drying up of the Gobi Sea and the dry seasons of the Gobi Desert not only gave rise to the double-humped camel, but also to the fat-tailed sheep. This sheep, crossing with the more widely dispersed urial or moufflon, gave us the sheep which started their westward and northward migrations from the eastern shores of the Mediterranean as already described, from which ultimately sprang the Merino and British types. Jacob's breeding experiments, as described in Genesis, give us the key to the change in colour of the fleece from brown to white.

The fat-tailed, fat-rumped, and broad-tailed sheep are only inter-

PLATE XXVI

TYPES OF BRITISH PEDIGREE SHEEP BREEDS.

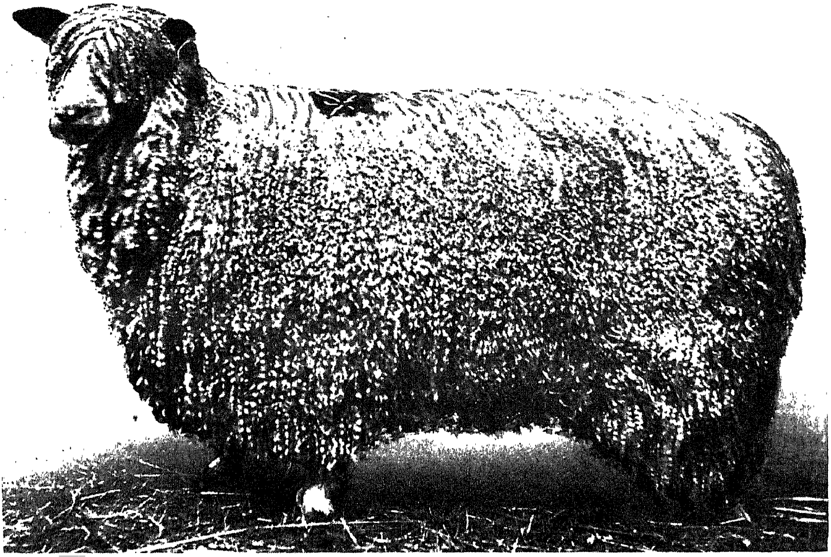

FIG. I.—WENSLEYDALE.

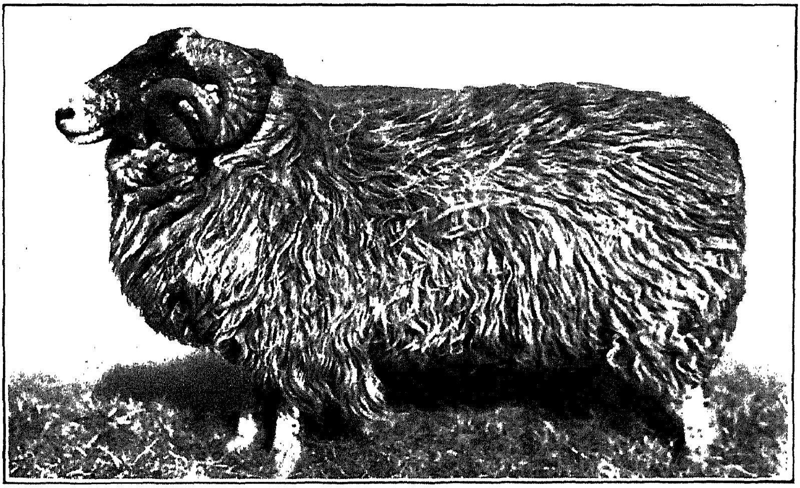

FIG. 2.—SWALEDALE.

To face p. 1332

WOOL (*Continued*)—

esting in a minor way from the wool point of view; East Indian wools come largely from this type of sheep, but are of minor importance in comparison with wools coming from the British and Merino strains.

Classification of British Sheep—The classification of British sheep in accordance with the quality of wool they produce is very simple in the light of the foregoing suggestions. The following is the most useful classification to adopt:

British sheep:
  Mountain (Blackface, Herdwick, Cheviot, Welsh, etc.).
  Lustre (Lincoln, Wensleydale, Devon Long, etc.).
  Down (Southdown, Shropshire, Ryeland, etc.).

The Mountain breeds are still of a rough, small-bodied type, and, if our surmise of migration be correct, not very different from the sheep brought to these islands by our Nordic forefathers. But even these rough sheep are rendered much more uniform in type by selection, some Blackfaced flocks being remarkable in this respect. A good Blackface ram has been known to sell for nearly £1,000. The Herdwick sheep possesses a rougher coat than the Blackface, but the Cheviot and Welsh are distinctly refined Mountain breeds, having been crossed with the British "Down" type of sheep.

The Lincoln sheep is the typical big sheep—improved in bodily size and contour, and carrying long lustre wool. The Leicester, Wensleydale, Cotswold, Devon Long, etc., sheep are all of the same type, and are obviously bred for rich pasturage. (See Plate XXVI, Figs. 1 and 2.)

The Down sheep seem to be a cross of a small British type with the Mediterranean type of sheep, being specially suited to the Down grass lands of the southern counties. Southdown, Shropshire, Suffolk, Dorset Horn, Oxford Down, etc., are representative of this type of sheep. (See Plate XXVII.)

Classification of Merino Sheep—The classification of Merino sheep is even simpler than the foregoing. Thus, the Mediterranean type of sheep reached its culminating point in Spain at the end of the eighteenth and beginning of the nineteenth century. From Spain it passed to Saxony and Silesia, and then to the Cape of Good Hope and Botany Bay (New South Wales). It was about the middle of the last century that huge supplies of merino wool were grown in New South Wales and shipped to Europe from Botany Bay—hence these fine merino wools, wherever they come from, are usually referred to as "botany" wools. The Merino sheep is now the basis of the flocks in Australasia, South Africa, and South America. In New Zealand and South America, however, the best types of British sheep have been introduced—mostly prize rams for which fabulous sums of money have been paid—so that large quantities of cross-bred wools are produced. The cross-bred wools, while valuable, are not so much sought after as the finer merino wools, but the demands for a good mutton "carcase" have thrown the New Zealand sheep breeders, particularly, along this line, so that now there are very few pure Merino sheep in New Zealand. (See Plate XXVIII, Fig. 1.)

WOOL (*Continued*)—

The most famous Merino-British cross is that of the Lincoln and the Merino. From this cross, by selection rather along Mendelian lines, the famous Corriedale sheep has been produced—perhaps the best example of a dual purpose sheep in the world. In South America the Lincoln-Merino cross is much in evidence, but in the extreme south—particularly in Patagonia and Punta Arenas—the Romney Marsh-Merino cross is much more in evidence, as this sheep stands up best to the very severe winters and the snow of this part of the world.

Characteristics of the Wool Fibre—Before proceeding to a detailed consideration of wool it will be well to define clearly the characteristic features of the wool fibre and, more particularly, to show in what respects it differs from hair. This really is essential, because while at one extreme there is wool and at the other extreme hair, there are many intermediate types that are neither the one nor the other which can only be defined in terms of the extremes.

The true wool fibre is a twofold structure—viz., cortex or main body stuff, and the cuticle or the scale-like structure surrounding the cortex which gives the wool fibre, under the microscope, its serrated appearance. The scales or serratures vary considerably in size and shape following the breed of the sheep, but are always in evidence in the true wool-fibre and will usually serve to distinguish wool from other fibres.

Hair is usually threefold in structure, possessing, as well as cortex and scales, a central core or medulla which if present in the case of the wool fibre is considered to reduce it almost to the level of hair. An even more important distinction is the mosaic texture of the exterior scales of the true hair fibre: under the microscope there is no danger of mistaking the one for the other, save in the case of nondescript fibres.

Wool fibres are usually much finer than hair fibres, varying from about $\frac{1}{500}$ to $\frac{1}{2000}$ in., while hair fibres vary from about $\frac{1}{150}$ to perhaps $\frac{1}{500}$ in. The typical hair fibre as it grows, for example, on the moufflon or urial is comparatively short and stiff, and the fine under-wool may be as long or longer. The strong hair fibre, however, growing on the Blackface or Herdwick is the longest fibre of the fleece, and the fine under-wool is much shorter. On such fleeces are found fibres representing almost a complete gamut from wool to hair. Most of our domesticated sheep, however, have been selected towards wool for many generations, so that such sheep as the Cheviot, Wensleydale, Leicester, Southdown, Dorset Horn, etc., are practically uni-fibred sheep, and the fibre is wool, not hair. On the finest fleeces, however, there is sometimes to be noted a reversion to the ancestral double coat, what is known as "kemp" fibre being but a relic of the original outer hair coat. Most Merino lambs are born with an outer coat of hair or "kemp," but shed it quite early in life and do not regrow it.

The "fur" type of fibre is best represented by camel hair and alpaca (also a camel). While this type of fibre shows distinct scales, it possesses a slipperiness not usually found in the wool fibre. But the truth is that we are not yet certain of what truly constitutes either wool, hair, or fur fibres from the structural point of view. The most

PLATE XXVII

TYPES OF BRITISH PEDIGREE SHEEP BREEDS.

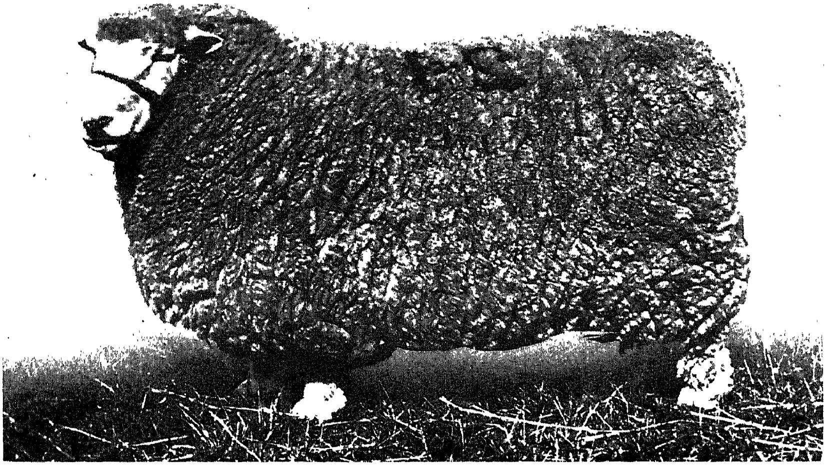

FIG. I.—ROMNEY MARSH.

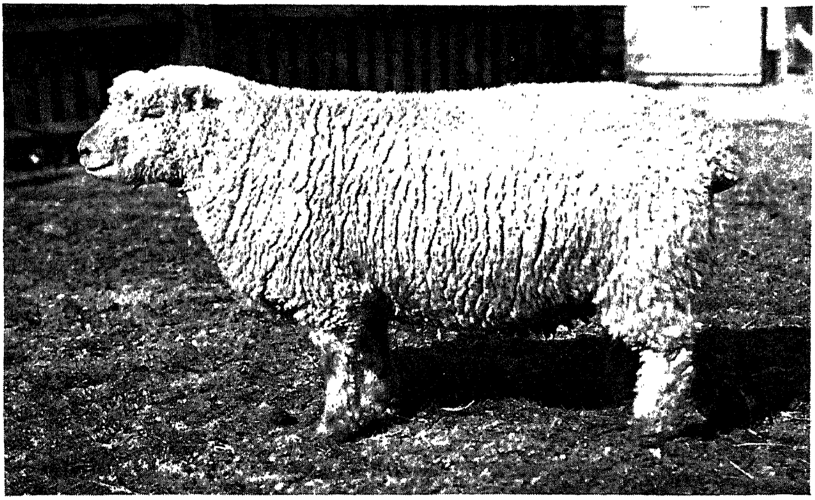

FIG. 2.—SOUTHDOWN.

To face p. 1334

WOOL (*Continued*)—

hopeful investigations along this line are being conducted by Mr. J. B. Speakman and Mr. W. T. Astbury in the University of Leeds, the latter working along the line of X-ray analysis. Chemical analysis is perhaps rather further ahead, for we do know that in the wool fibre sulphur plays an important part, whereas it is absent from the skin (or gelatin). Thus, the suggestion to gelatinize waste and old wool products and spin an artificial filament after the manner of artificial silk spinning is not likely to prove fruitful in producing an artificial wool at all comparable with the natural fibre, the "stuff" of which has a much more complex physico-chemical structure than that of gelatine.

All wool fleeces as sheared from the sheep contain impurities of two types—natural and acquired. The natural impurities consist of the wool fats, potassium and other salts, and the amount of water natural to the wool fibre (about 16 per cent. on the weight of the dry wool). The acquired impurities are soil, additional water, and, in some cases, vegetable matter—in Colonial wools, "burrs" in particular.

Wool washing on the sheep's back as practised in Britain removes about 40 per cent. of the total impurities, the remaining 60 per cent. being removed in the subsequent emulsion scouring operation. The approximate yields of clean wool for representative types is as follows:

Type of Wool.	*Clean Wool.*	*Water*	*Soil.*	*Fat.*	*Potash Salts.*	*Organic Matter Burnt Off.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Lincoln ..	73·3	13·4	5·32	3·77	2·06	1·63
Merino ..	45·0	9·0	13·00	24·00	4·00	6·00
Corriedale ..	54·0	13·0	10·00	12·00	5·90	6·00
Southdown ..	50·0	11·0	16·00	10·00	5·20	8·00

The "Quality" of Wool—Before proceeding to the consideration of the most important wools an attempt must be made to realize what is implied by the term "quality." The woolsorter sorts, say, a fleece of Lincoln wool into 40's, 36's, 32's, and "britch" qualities—what does he mean by these "quality" indications? The word "quality" might easily be supposed to have reference to "fibre stuff," but such is not really the case. For if the wool handles more plastic, or harder, or softer, the woolsorter will say so and he will not refer to this as a "quality" in his sense of the word at all. Quality is essentially fibre diameter (or fineness), and is judged probably by both eye and touch. That quality may be decided by touch is probably due to the fact that a given fibre diameter usually gives a corresponding handle—although there are possibly some few exceptions to this rule. Thus, "wool qualities" may be defined by fibre diameter measurements—measurements made directly by the eyepiece micrometer or more tediously but more accurately by the micro-balance on the volume/length basis. The most useful formula for obtaining the

WOOL (*Continued*)—

quality number for any fibre diameter is that of Mr. Henry Wilkinson, in which if d=diameter of fibre in fractions of an inch, and q=the quality number, then

$$d=\frac{1}{1\cdot52\ q\ 1\cdot68}$$

or

$$\text{Log}\ q=-\frac{1}{1\cdot6}(\text{Log}\ 1\cdot52+\text{Log}\ d).$$

From this equation the following relationships have been worked out:

The Relationship between Quality Number and Fibre Diameter.

Bradford Quality Number.	*Diameter by Formula.*	*Bradford Quality Number.*	*Diameter by Formula.*
	Ins.		Ins.
28's	$\frac{1}{314}$	54's	$\frac{1}{899}$
32's	$\frac{1}{389}$	56's	$\frac{1}{953}$
36's	$\frac{1}{470}$	58's	$\frac{1}{1007}$
40's	$\frac{1}{556}$	60's	$\frac{1}{1064}$
44's	$\frac{1}{648}$	64's	$\frac{1}{1180}$
46's	$\frac{1}{696}$	68's	$\frac{1}{1299}$
48's	$\frac{1}{744}$	70's	$\frac{1}{1361}$
50's	$\frac{1}{795}$	80's	$\frac{1}{1686}$
52's	$\frac{1}{846}$	90's	$\frac{1}{2034}$

Perhaps slight corrections should be applied to this list at its two extremes—28's, 32's, and 36's should be just a little finer, and 80's, 90's, and 100's a little coarser; but the correction is so slight that for practical purposes the list as it stands may be relied upon.

Length is not taken into account in the quality number, but is often expressed in addition. Thus, a botany woolsorter will sort a "long" and a "short" 60's quality. Crimp is certainly more closely allied to quality than is length. Thus an 80's quality of botany wool will be crimped to twenty-four per inch, while a 36's Lincoln will have two or three crimps per inch. But the relationship between "crimp" and "quality" is by no means constant.

British Wools—With the foregoing particulars in mind, typical examples of British and Merino wools may now be more fully considered. The following classification may be usefully followed (Plate XXIX, Figs. 1 and 2):

Typical British wools:
    Mountain.
    Half-bred or Demi-Lustre (Lustre × Mountain).
    Lustres.
    Demi-Lustre (Down × Lustre).
    Down.

There are four Mountain wools produced respectively by the Blackface, the Herdwick, the Cheviot, and the Welsh Mountain sheep. The

PLATE XXVIII

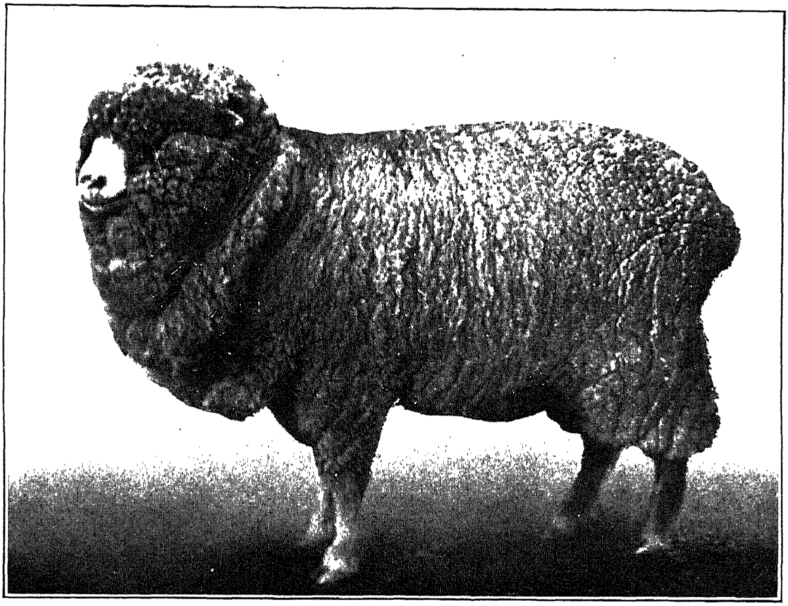

FIG. I.—AUSTRALIAN MERINO.

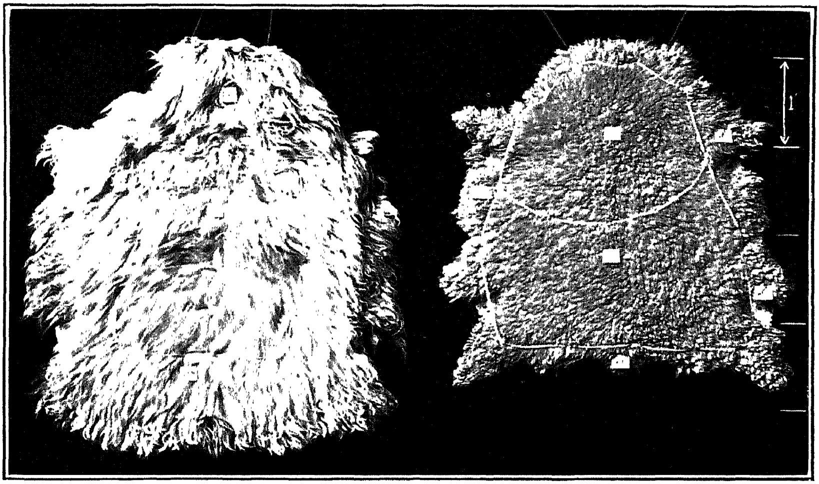

FIG. 2.—WOOLLED SKINS OF (LEFT) MOUNTAIN AND (RIGHT) DOWN SHEEP.

From the Wools and Woolled Skins collected by the Royal Agricultural Society of England for the University of Leeds.

WOOL (*Continued*)—

Blackface is the sheep found upon the heather tracts of the Southern Pennines right up into the Highlands of Scotland. Until quite recently sheep tracks allowing of the driving of these sheep from the north of Scotland to the south of Yorkshire were open, supporting the suggested migration southwards of the "Nordic" sheep. There are several varieties of this breed, such as Swaledale, Lonk, etc., all important and, in their way, different, but bearing marked traces of their common progenitor. The Herdwick also may have a Blackface basis, but it has been very considerably modified. It is said to be in part due to sheep which swam ashore from one of the wrecked ships of the Spanish Armada; and there may be some truth in this, as it is the only piebald sheep in Britain, and does correspond, to some extent, with the common Spanish sheep (not Merino). Beautiful tweeds in natural colours may be produced by "colour sorting" Herdwick fleeces into about four lots, grading from dark brown to a fawn white. The quality of the two wools—Blackface and Herdwick—is approximately 28's, but the Herdwick carries much more bottom fine fibre than the Blackface, and consequently is not so uniform.

That "race" plays as important a part as "environment" is at once realized on passing from the Blackface to the Cheviot sheep. Of course, the grassy slopes of the Cheviot Hills are very different from the heather-clad hills of the Pennines, but a glance at the Cheviot sheep shows a race change which has no doubt come about by the sheep farmer striving to adapt race to environment. While Cheviot wool is longish and strong, it is distinctly of the "Down" type, and is better bred and more uniform than the normal Blackface wool, and is pure white. Thus it may be made into a much finer type of "tweed."

The Welsh sheep seems to have been bred especially to stand up against the wetness of the Welsh mountains; it is said that the Scotch Blackface can only stand up against the climate on one hill in Wales, presumably the dryest. The dense coat of the Welsh sheep is of the "Down" type of wool, and many attempts have been made to improve it, but the Welsh farmer maintains that to breed out the "kemp" or strong fibres by careful selection produces an enfeebled flock which cannot weather the storms of the Welsh mountains and hills. The Department of Agriculture of the University College of North Wales, Bangor, is making strenuous attempts to carry out all possible improvements, and the validity of the farmers' arguments are being fully tested.

There are other moorland or hill sheep, but these are not considered here, as their wools have been so much improved that they rank higher than the Mountain class.

Between the Mountain and the Lustre wools come the half-bred or demi-lustre wools. These result from the crossing of, say, the Blackface ewes with a better bred Lustre wool ram—usually a Wensleydale. Thus what is known as the "Masham" is the first cross Wensleydale-Blackface; and this half-bred sheep crossed again with the Wensleydale

WOOL (*Continued*)—

produces the "Ripon," which wool, owing to the potency of the Wensleydale, is practically a Lustre wool.

A similar cross is to be noted between the Cheviot and the Border Leicester, in this case a well-recognized wool termed "North" being produced.

Of the Lustre wools, the most remarkable is the Wensleydale, the ringlets into which the fleece divides itself possessing a most beautiful spiral, pearly appearance. The Border Leicester and the Dartmoor wools are the next best, with English Leicester and Lincoln as the typical examples of normal Lustre wool. Lustre wools are also produced by Cotswold (one of the oldest breeds), Devon Longwool, and South Devon sheep. One or other of the Lustre breeds of sheep is to be found wherever the pasturage is sufficiently luxuriant. Thus, the lowlands of east Yorkshire carry Leicesters, and some of the richest lands of northern Scotland carry Border Leicesters. There always appears to be an environmental action on the coat of the sheep readily perceptible in the case of the Lustre breeds. This is said to be due to the presence or absence of potash, or perhaps more particularly iodine, in the soil. Little reliable knowledge is to hand, however, with reference to the effects of environment and "feed" on the fleece of the sheep, but promising researches are already in hand both at home and in the overseas Dominions.

The crossing of the Lustre breeds with the Down breeds gives the typical Demi-Lustre wool. Perhaps the best example of this is the Romney Marsh wool (Plate XXVII, Fig. 1). The Romney Marsh sheep has been specially bred as a sheep to withstand "fluke" and "foot rot" on the low-lying lands of Romney Marsh (Kent), but it obviously has both a "Lustre" and a "Down" basis. This sheep—in contradistinction to the Border Leicester—is "fringed" and "feathered," and being a big sheep carries a big fleece often weighing over 12 lbs. The fleece is peculiar in that it usually carries some very fine fibres—finer than much Merino wool. Unfortunately it also carries at times a strong fibre—medullated—which gives a bad "spin" and has caused the Bradford spinners to complain to the New Zealand sheep-breeder about Romneys and Romney crosses: curious to relate, there do not seem to be the same objections against the South American-Romney crosses. Here again is matter demanding investigation! Cheviot wool, which has already been dealt with as a Mountain wool, is sometimes classed as a Demi-Lustre. Exmoor has been so much improved of late that it may well be ranked as a Demi-Lustre wool. Demi-Lustre wools are also produced in large quantity by Suffolk, Shropshire, Hampshire, and Oxford Down crosses with the recognized Lustre breeds, and even the Suffolk × Blackface may sometimes be so classed.

Of the "Down" wools that of Southdown ranks first. Not a hundred years ago "colour" was much in evidence in Southdown flocks: to-day, excepting for the "dun face," the Southdown is one of the three white Down flocks recognized as being free from "black hair." Dorset Horn is the whitest of the Down wools, being followed very closely by Dorset Down, while Ryeland has been much improved in

PLATE XXIX

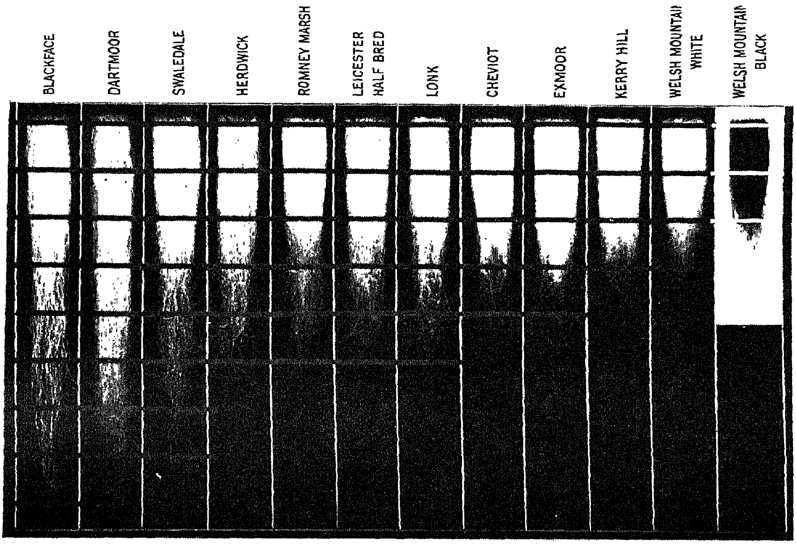

FIG. 1.—BRITISH PEDIGREE WOOL TOPS.

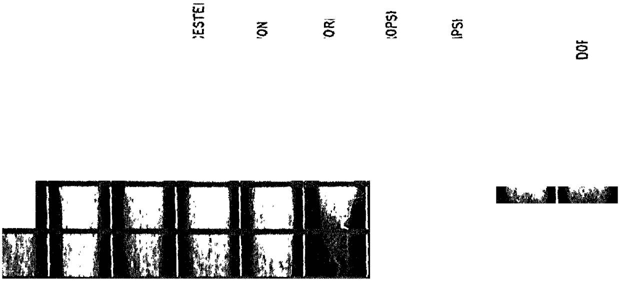

FIG. 2.—BRITISH PEDIGREE WOOL TOPS.
From the Wools and Woolled Skins collected by the Royal Agricultural Society of England for the University of Leeds.

To face p. 1338

WOOL (*Continued*)—

this respect. The presence of black fibres in the other Down wools lowers their market value by pence per pound.

The Down breeds of sheep are by no means pure bred. The Suffolk has been produced by crossing the old Blackfaced Norfolk and the Southdown; Oxford Down has Lustre blood in it, and the Ryeland appears to have been crossed more than once with the Merino.

The following list is a useful summary of the four classes of British wools:

Breed.	*Average Diameter.*	*Average Length.*	*Average Waves per 1 Inch.*	*Percentage of Black Fibre.*	*Percentage of Kemp.*
Mountain :	Ins.	Ins.			
Blackface	$\frac{1}{460}$	11·22	—	14	15
Herdwick	$\frac{1}{525}$	7·62	—	30	20*
Welsh (White) ..	$\frac{1}{502}$	3·67	4·60	0	7
Lonk	$\frac{1}{620}$	6·72	3·65	12	0
Swaledale Dales ..	$\frac{1}{675}$	7·70	—	18	12
Welsh (Black) ..	$\frac{1}{740}$	2·02	5·45	96	5
Lustre :					
Lincoln	$\frac{1}{562}$	12·00	2·30	0	0
Devon Longwool ..	$\frac{1}{582}$	9·10	1·77	0	0
South Devon ..	$\frac{1}{504}$	10·95	3·55	0	0
Leicester	$\frac{1}{614}$	12·02	2·05	0	0
Dartmoor	$\frac{1}{642}$	11·15	1·75	1	0
Cotswold	$\frac{1}{643}$	10·75	2·27	0	0
Wensleydale ..	$\frac{1}{647}$	12·70	2·42	10†	0
Border Leicester ..	$\frac{1}{712}$	7·85	3·30	0	1
Demi-Lustre :					
Cheviot	$\frac{1}{681}$	4·70	5·80	2	3
Exmoor Horn ..	$\frac{1}{692}$	3·81	6·95	0	1
Romney Marsh or Kent ..	$\frac{1}{701}$	6·30	4·65	0	0
Half-Bred Leicester	$\frac{1}{703}$	6·10	4·80	1	0
Kerry Hill ..	$\frac{1}{714}$	3·82	4·20	0	1
Down :					
Dorset Down ..	$\frac{1}{651}$	2·90	6·00	0	0
Dorset Horn ..	$\frac{1}{658}$	3·17	5·80	0	1
Oxford Down ..	$\frac{1}{700}$	4·03	6·40	10	0
Suffolk Down ..	$\frac{1}{723}$	3·95	7·10	8	0
Hampshire ..	$\frac{1}{737}$	3·70	7·60	7	0
Ryeland	$\frac{1}{741}$	4·40	5·75	0	0
Shropshire ..	$\frac{1}{817}$	2·50	6·10	3	0
Southdown ..	$\frac{1}{870}$	3·67	9·60	0	0
Merino :					
60's Quality ..	$\frac{1}{1000}$	3·5	16·00	0	0
70's Quality ..	$\frac{1}{1200}$	3·5	20·00	0	0
80's Quality ..	$\frac{1}{1400}$	3·0	24·00	0	0

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* A piebald sheep.

† The Wensleydale produces pure white or full black or silver-grey fleeces—never black fibres interspersed among the white fibres as in the case of the

WOOL (*Continued*)—

Although the Merino sheep is non-existent in Great Britain, save for a small flock of the Camden Park strain (Macarthur's original Merinos) in Herefordshire, and a small flock of Peruvian Merinos near Leeds, its potentiality as a "crossing" sheep in its improved forms justifies reference to it here. About a hundred years ago the British wool manufacturers drew their supplies of Merino wool from Spain. A little later the Merino wools of Saxony and Silesia dominated the trade, to give way about 1840 to the Australian Merino, which has held foremost place ever since. Since 1860, South Africa has developed a wool industry—almost entirely Merino—which is still expanding; South America has also developed a Merino wool industry of considerable importance, chiefly centred in Uruguay and the Argentine. A more recent development, however, is that of the cross-bred or dual purpose type of sheep, in which New Zealand has outstripped all other countries, although Australia and South America produce large quantities of these sheep and their wools.

Particulars respecting Merino wools are given along with the British wools as a means of comparison.

Experimental Breeding—Improvements in the breed of sheep in any desired direction may be produced by: (*a*) selection within the breed, and by (*b*) cross-breeding and selection from the crosses. Australasia having developed a pure Merino strain based upon a small sheep yielding about a 4-lb. fleece, was not satisfied and proceeded to evolve a sheep giving (*a*) a larger carcase, and (*b*) a heavier fleece, by both the foregoing processes. Thus, pedigree British breeds of sheep were taken out and definite cross-bred flocks produced, the most important of these being the Corriedale—the Lincoln × Merino. But it is probable that British blood—particularly Leicester—was introduced into many of the Merino flocks, so that before long it was found possible to select within certain flocks larger-bodied, heavier-fleeced animals well within the Merino characteristics. Thus, on the two lines of breeding indicated, Australia has evolved Merino flocks in which a large-bodied sheep carried a Merino fleece up to 70's quality, weighing on the average 10 lbs., as against the 4 lbs. of the original Merino.

About 1912, the late Professor T. B. Wood, of Cambridge, definitely attempted to combine the wool qualities of certain West Australian Merinos with the body qualities of Shropshire sheep on Mendelian lines. In this particular cross the fine wool seemed to segregate with a small body even in the first generation. Owing to Mr. Bailley, of Clare College, who had charge of the experiment, being killed in the Great War, the experiment was abandoned. More recently Peruvian Merino sheep have been introduced into Britain and have shown that in certain parts of the country they can stand up to the climate very satisfactorily.

These and other experiments with Wembley Merino rams have shown that most Merino types do not do well in this country, but that at least one type—the Peruvian—will thrive. The Peruvian, how-

WOOL (*Continued*)—

ever, is a miserable mutton type of sheep, so that the problem really is—Can the climate-withstanding qualities of the Peruvian Merino be incorporated with larger body and wool-yielding qualities? If this can be done there is a future for the Merino even in these islands.

All the important Merino crosses in this country were shown by the University of Leeds at the Royal Agricultural Show, Harrogate, in 1929, and the Corriedale sheep claimed universal commendation. Thus, the production of the ideal fine-woolled large-bodied sheep suited to the climatic conditions of Britain is still a dominant problem for British geneticists.

Wool Manufacturing—Wools for manufacturing purposes may be classed as:

Fine: $\frac{1}{1000}$ to $\frac{1}{1400}$ in. diameter (60's to 80's quality).
Medium: $\frac{1}{600}$ to $\frac{1}{1000}$ in. diameter (46's to 60's quality).
Coarse: $\frac{1}{200}$ to $\frac{1}{600}$ in. diameter (28's to 46's quality).

It looks as though the reply of the wool manufacturer to the artificial silk menace is the production of exceedingly fine wool fabrics, and these require the finest, best grown wools for their successful manufacture. It is just conceivable that some of this fine wool might be grown in Britain if the new type of Merino sheep indicated can be evolved.

What are known as medium wools are well represented in the British Isles by the Down, Down crosses, and the finer Lustre wools. Britain has provided the world stock for this type of wool.

The coarser wools are also essentially British wools, with the exception of certain wools for carpet manufacture known as East Indian. Blackface wool is the chief of the British strong wool types. Owing to both the Italian and the United States demand, this wool has both risen and maintained its value in the wool market. It may be found that this wool is the most difficult to match with a synthetic fibre, and, owing to its cheapness, it certainly will be the most difficult to compete against from the point of view of economics.

It remains to be seen whether the artificial fibre menace to the wool trade has reached its climax. There are indications that it has, and if so, it looks as though there should be a period of growing prosperity for the wool grower and also for the wool manufacturer. The example of artificial indigo, however, should serve as a note of warning, and it behoves wool grower and wool manufacturer alike to enlist the sympathies and help of both scientist and economist in their efforts to achieve and maintain industrial supremacy. A. F. B.

YAVEL—Yavel is the name given to a second straw crop following, say, a clover ley or a root crop. The first corn crop after a clover ley would be the ley corn; if a second straw crop is taken, it is then known as "yavel." It is synonymous with cross-cropping, and is usually regarded as bad farming owing to the dirty condition in which a second corn crop leaves the land.

YEAST—A mass of fungous growth obtained from worts of barley, rye, maize, etc., differing somewhat in properties according to the source. It consists for the most part of microscopic cells of *Saccharomyces cerevisiæ*, and these grow by budding. Between 3° and 35° C. these cells have the power of inducing alcoholic fermentation in dilute sugar solutions, but they are killed by alcohol of 14 per cent. strength. The action of yeasts differs with the enzymes contained. Yeast is said to contain large quantities of vitamins (*q.v.*). The patent food "Marmite" is made from brewery yeast. It has considerable use in bread-making, by inducing rising due to the carbon dioxide given off in the fermentative changes set up; in fact, it is to the yeast incorporated with the dough that the characteristic honeycomb or spongy structure of bread is mainly due. In Germany, a yeast is grown on sugary or starchy waste products from various manufacturing processes. These are supplied with nitrogen in the form of ammonium salts, and the yeast resulting is found to contain about 50 per cent. of nitrogenous matter when dried. It is used for feeding cattle as a concentrate, and is, indeed, said to be quite fit for human food. (See Dried Yeast, under Feeding Stuffs.)

YELLOW SUCKLING CLOVER—See Legumes, Breeding of Herbage.

YIELD TRIALS—It is quite easy to produce new hybrids; from a single cross fertilization between two varieties of a cereal one can select thousands of strains, differing more or less in some character from all the others. Whether any particular strain is worth preserving will depend upon many things, but among them one is indispensable: the yield *must be sufficiently high to make the crop profitable.*

Similarly new manures or combinations of manure are continually being proposed, and the one condition of their use is that the increase in yield which they provoke must be such as to pay for the cost of applying them.

As improvements are nowadays not likely to be very great, it becomes necessary to estimate comparative yields very closely, and this is not as simple a matter as it may appear at first sight.

In the case of selection of strains of high yield the difficulties are of two kinds: (1) That similar environmental conditions of weather, soil, etc., may evoke different responses in strains, even though nearly related, of the same race; one may be better suited than another by a light soil, or a dry summer, and so on. (2) Quite apart from characteristics of this kind, the soil on which the plants are grown is never uniform, so that differences in yield arise which have nothing to do with the strains which are being tested. Similar considerations apply to manurial and other trials.

Clearly, difficulties of the first kind can only be surmounted by repeated trials in many seasons and in all relevant types of soil and situation; but until we have arrived at some method of estimating what error is introduced into our conclusions by difficulties of the second kind and of reducing this error to manageable dimensions, we are not in a position to say whether observed differences in yield are

YIELD TRIALS (*Continued*)—

due to the different strains, to their differential response to their environment, or merely to chance variation in the soil on which they have been grown.

In what follows it is proposed first of all to give a brief account of some of the methods of arranging yield trials which have been introduced during the past twenty-five years, then to indicate the general reasoning which enables us to estimate the degree of reliance which we can place on our results, and, finally, to work out two examples of the actual calculation of such estimates.

Although it must have been recognized long ago that experiments to determine comparative yields were not quite straightforward, the science of planning such experiments was not investigated up to twenty-five years ago, and the practice of the art is only now becoming general.

It is true that sound results had been obtained by long continued trials carried out over a wide area with comparatively large plots, notably by the Danish Royal Agricultural Society and by the Irish Department of Agriculture ("Slutningsberetning om Maltbyg- og Hvedeudvalgets Virksomhed Vedrorende Byg- og Hvedeavlen" Chr. Sonne, Foredrag i Det Kgl. Danske Landhusholdnings-Selskab den, 1 April, 1903; H. Hunter, "The Barley Crop," Ernest Benn, London), but, on the other hand, there was a tremendous amount of energy wasted on experiments from which, as we now know, it was impossible to have reached reliable conclusions.

To obtain decisive results in this way it is not only necessary to work on a very large scale (in the Irish work Archer and Goldthorpe barleys were compared fifty-one times over a period of six years), but the differences to be determined have to be comparatively large, for a single one-acre plot must exceed another by at least 25 per cent. if it is to be considered significantly better.

It was not, however, until 1910-11, with the publication of papers by Stratton and Wood, Mercer and Hall, and Montgomery (T. B. Wood and F. J. M. Stratton, "The Interpretation of Experimental Results," *J. Agric. Sci.*, vol. iii., No. 4; W. Mercer and A. D. Hall, "Experimental Error of Field Trials," *J. Agric. Sci.*, vol. iv., No. 2; E. G. Montgomery, "Variation in Yield and Methods of Arranging Plots to secure Comparative Results," *Neb. Agric. Expt. Stat. 25th Ann. Rept.*, and "Experiments in Wheat Breeding," *U.S. Dept. Agric. Bur. Plant Indust. Bul.* 269), that the real difficulties of the problem became fully apparent. Each of these papers dealt with the yields on the component parts of an area of land. Stratton and Wood dealt with $\frac{9}{10}$ acre of mangolds in plots of $\frac{1}{1000}$ acre; Mercer and Hall with 1 acre of wheat in $\frac{1}{500}$-acre plots, and also with 1 acre of mangolds in $\frac{1}{200}$-acre plots; Montgomery, for two years in succession, with wheat grown on the same $\frac{7}{45}$ acre and harvested in $\frac{1}{1440}$-acre plots.

In each case the area was chosen as being particularly uniform in appearance, in each case the yields showed unexpected variability. Further, this variability *was not random* (see section on Randomness.

YIELD TRIALS (*Continued*)—

nor, on the other hand, was it, except in the very slightest degree, regular. There was, it is true, a general tendency for plots at one end or side of the area to give higher yields than those at the other, but the " contours of fertility," though they existed, showed no exact parallelism (unpublished work by R. A. Fisher).

This suggested at once, firstly, that great accuracy would be obtained if plots whose yields are to be compared were sited closely together so that chance variations in the soil fertility should be shared as equally as possible; and, secondly, that to obtain this close siting the plots must be kept as small as it is convenient to work with, especially if many variants are being tested.

But, besides convenience in working, there is another limit to the smallness of experimental plots.

This is due to the fact that the outside of a plot does not represent a field crop, since it is in contact with plants of some other variety, or subjected to another method of treatment, and experience has shown (T. A. Kiesselbach, " Plot Competition as a Source of Error in Crop Tests," *J. Amer. Soc. Agron.*, vol. xi.; E. S. Beaven, " Pedigree Seed Corn," *J.R.A.S.E.*, vol. lxx., 1909) that plants growing alongside one another are in strong competition for both food and light. Nor can this difficulty be overcome by leaving unoccupied space between the plots, for even in this case the outside plants are only representative of the outside of a field where the plants are able to get excessive nourishment, and, of course, the outside forms a small part of a large field, but a very sensible proportion of a small plot. It is, therefore, necessary either to have the plots so large that the " border effect " is negligible, or to discard the outside rows and plants from the portion which is to be weighed.

The first system of yield trials based on a realization of the foregoing facts was Dr. Beaven's " chessboard " system of square yard plots (E. S. Beaven, *ibid.*; " Student," " On Testing Varieties of Cereals," *Biometrika*, vol. xv., pp. 272-293), which was, in fact, in use at Warminster in 1909 before the publication of the three papers which have been cited.

This system, which has become the standard method of comparing the yields of varieties of cereals under wire cages, derives its name from the fact that the plots are square. Each square measures 4 ft. along the side, and in it are sown eight rows of seeds at 6 ins. between the rows, the seeds being planted 2 ins. apart in the rows. At harvest, however, the two outside rows are rejected, and also plants in the 6 ins. at both ends of the other rows. Thus interference with neighbouring varieties is reduced to a very small amount.

The arrangement of the plots in the experimental area merits attention, and should fulfil the following conditions:

(1) The mean position of each strain tested should be the same, to counteract the effects of a possible " fertility slope."

(2) Different plots of the same strain should be spaced so as not to be needlessly close to one another; each strain then shares as far as possible in the casual vicissitudes of the experimental area.

YIELD TRIALS (*Continued*)—

Beaven's own arrangement was as follows:

A	F	C	H	E	B	G	D
B	G	D	A	F	C	H	E
C	H	E	B	G	D	A	F
D	A	F	C	H	E	B	G
E	B	G	D	A	F	C	H.

the panel of forty plots being repeated as often as is considered necessary, generally, in his case, four times.

It will be seen that this evens up a fertility slope across the panel, but that the earlier letters are more to the left than the later by a small amount—A averages $\frac{7}{10}$ of a square to the left of the centre line, H the same amount to the right of it—and to correct for this, the present writer has suggested that alternate panels should be reversed, H being written for A, and so forth. This contravenes condition (2) at the places where the panels join, but not to a very serious extent. Even so, this arrangement has been criticized on the ground that a regular pattern makes it impossible to assume that the error of estimation is random.

Be this as it may, such an arrangement has two solid advantages for this particular purpose over partly random or controlled random arrangements, such as Fisher's Randomized blocks or Latin Squares which are described below. These advantages are: (1) That the chances of mistake are lessened by a regular system, and such mistakes have been known to occur even with the most experienced workers; (2) that the use of such plots for observation purposes is very much facilitated by the ease with which a particular strain may be picked out.

The chessboard arrangement has been of great practical service in testing barley hybrids, and, in fact, the two varieties of barley most popular at the present time in the British Isles, Plumage-Archer and Spratt-Archer (see Barley), were both tried out in wire cages in this way, and found to be superior to their competitors before proceeding to trial on a larger scale.

On the other hand, selections which have proved successful in the cage have not always succeeded in the field, though this is probably due to the fact that there is a difference between horticultural methods such as are there used and the ordinary procedure of agriculture. It may also be due to the wire covering, and experiments which Mr. M. Caffrey is conducting at the Royal Albert Agricultural College at Glasnevin, Dublin, in the open, may throw light on this point.

Before considering large-scale work, it is necessary to refer to "rod rows," *i.e.*, plots consisting of a single row of plants one rod in length. These have been used largely in American work (H. K. Hayes and A. C. Arny, "Experiments in Field Technique in Rod Row Tests,"

YIELD TRIALS (*Continued*)—

J. Agric. Res., vol. xi., p. 399), but in their original form, though, of course, very convenient for purposes of observation, they are nearly useless for the determination of yield even when replicated many times. This follows from the fact noticed above, that the yield is due not only to the inherent quality of the seed, but also to the vigour or lack of vigour of its neighbours.

In a modified form, where three or more rows of the same variety are grown consecutively, and the outer rows rejected when determining yields, but retained if necessary for use as seed, the rod row system can give useful results if sufficient replications are made. Even so the area wasted by rejected border amounts to a large proportion of the whole (67 per cent. with three consecutive rows, 50 per cent. with four, as compared with 44 per cent. in the chessboard), so that the method is not recommended, except as a rough test at the stage where a large number of strains or hybrids is to be cut down by wholesale discards, while at the same time as much seed as possible is wanted for those selected for further trial (F. W. Hilgendorf, "Plant Breeding Methods Results," *N. Z. J. Agric.*, March, 1928).

Large-Scale Work—*Beaven's Half-Drill Strip Method*—We now come to methods of carrying out experiments on an agricultural scale, and here, again, Beaven has introduced a method which takes full advantage of the light thrown on the problem by the papers cited above (E. S. Beaven, "Trials of New Varieties of Cereals," *J. Min. Agric.*, vol. xxix., Nos. 4 and 5, 1922; "Student," *loc. cit.*).

In order to compare yields grown on areas as contiguous as possible, he took an ordinary seed drill of which he put the middle coulter out of action and divided the seed box into two halves. Seed of different strains having been put in the two halves, the drill is driven down the field, and wheeling at each end, it sows the strains as in Fig. 43. At harvest the outside drills of each half-drill strip—those in contact with the other strain—were pulled up by hand and discarded to avoid the "border effect," and each half-drill strip cut separately. If the two strains ripened simultaneously they were cut by a reaping machine, but, if not, one had to be cut by hand.

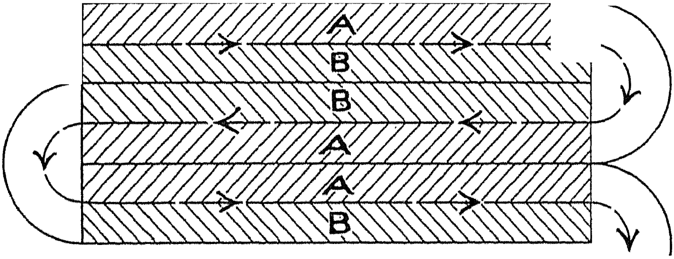


FIG. 43

YIELD TRIALS (*Continued*)—

Originally a machine was used which delivered a separate sheaf off each $\frac{1}{500}$ acre, but this procedure was criticized on the ground of lack of randomness, and was afterwards found not to be necessary, the gain in the apparent accuracy over the plan of weighing only the totals of each half-drill strip not being found worth the additional trouble.

The weight of each half-drill strip is then compared with its neighbour of the other strain, and the layout of long narrow plots placed closely together ensures that the error of the comparison shall be small.

To compensate for the probable fertility slope the series should begin and end with the same strain, and the following precautions be taken:

(1) The ground chosen for the experiment must be free from periodic changes of level, such as those left by having been laid down to grass in "lands," or, if present, the seed must be drilled across these "lands."

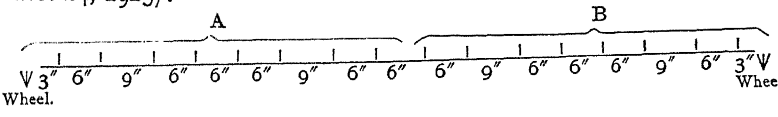
(2) The drills should run across those of the previous cultivation.

(3) The experimental area should be surrounded by at least one drill of the same kind of crop as is being experimented with.

(4) Great care must be taken when sowing to drive quite straight, so that the "inside" wheel of the machine may run as nearly as possible in the same track as it made when it was the "outside" wheel in the last journey in the other direction.

(5) After harvest the drilling must be checked by measuring the distances between the outside rows of corn, which may be appreciably different in the case of the two varieties owing to the horses pulling unequally, and this will favour that variety which has the wider gap. As, however, the gain will be approximately proportional to the gain in area, allowance can be made for this.

To avoid this difficulty Beaven now uses a special drill as follows (W. H. Parker, "Report on Trials of Four New Barleys," *J.N.I.A.B.*, No. 14, 1925):



As before, the seed box is divided so as to take two strains, but the coulters are spaced so that between each four rows, 6 ins. apart, there is a wider gap of 9 ins., enabling each four rows to be cut separately.

Half of the sets of four consist of two rows of each strain, and these are discarded at harvest; the others are thus arranged in the same manner as before (A B B A A . . . B A), and not only have the advantage that they are sown on equal areas whether the drill be driven straight or no, but they are also flanked by two discarded rows of their own kind, thus reducing interference to a minimum.

YIELD TRIALS (*Continued*)—

It will be seen that the half-drill strip can only compare two strains at a time, and if several are to be tested it is necessary to compare each with a " control." This is a serious limitation; nevertheless, the shape of the plots enables the comparison to be made with great accuracy.

This arrangement of plots also has been criticized on the ground that it is not random.

The application of the principle of long and very narrow strips thus introduced by Beaven for cereals can, of course, be applied to root crops, but for manurial experiments there would be danger of the benefit of the manure straying to the neighbouring plot. For these, the plots must be wider, and the method of their arrangement has been made a special study by Dr. Fisher, at Rothamsted. As a result he has evolved (1) " Randomized Blocks," and (2) the " Latin Square " (R. A. Fisher, " Statistical Methods for Research Workers," Oliver and Boyd, Edinburgh).

In the former he divides up the experimental area into blocks, which will contain one of each of the variants to be tested (varieties, manurial treatment, or whatever it may be). Within the block the arrangement is random, determined by some such method as dice throwing. The advantage is that since all the area of any one block is likely to be more uniform than the whole area, the trial within that block will be affected to a less extent by variations in soil fertility than if the plots were scattered about over the whole area, and yet the arrangement is random. The disadvantage is that in practice it may happen that the particular random arrangement adopted may result in one strain (or treatment) having a more favourable mean position than another: in a majority of the random blocks it may be on the north, and the north end more fertile than the south. Such a possibility is allowed for in the subsequent calculation, but the general effect is to introduce an unnecessary increase of uncertainty into the result: the error is larger than need be.

To meet this Fisher evolved the Latin Square, where the mean position of each variety is situated in the same place by making it occur in each row and in each column of a " square," repeating the " squares " as often as may be required. Thus four strains (A, B, C, and D) might be arranged in a square thus,

A	D	C	B
B	A	D	C
D	C	B	A
C	B	A	D

FIG. 44.

YIELD TRIALS (*Continued*)—

the actual position being obtained by dice throwing with increasing limitation, as, for example, after the top row has been fixed no further plot in the first column can be A, and so on.

This most ingenious arrangement is ideal from the point of view of interpretation, but care should be taken not to have the plots so large that they do not lie closely together, or the error of the results, accurately though it is estimated, may be so large as to make the experiments inconclusive.

The Latin Square need not, of course, be square; it will be of the same shape as any of its constituent plots. Thus, in the case of potatoes, where there is some evidence (R. N. Salaman, "The Determination of the Best Method for Estimating Potato Yields," etc., *J. Agric. Sci.*, vol. xiii., p. 361, 1923) that the "border" effect is negligible, the width of each "plot" might be a single drill, and the length (for four strains) one-quarter the length of the field; a number of such "squares" side by side would doubtless give results subject to a very small error.

At first sight it might seem that cereals might be tested by a combination of Beaven's half-drill strip with the Latin Square, but the practical difficulty of the time taken to clear out the seed boxes after every strip, or alternatively of driving the drill straight enough to be able to drill in one variety at a time, and then fill in with the others afterwards, seems to be insuperable, unless a drill with spare boxes and arrangements for changing them quickly could be devised for the purpose. In any case, room for turning the horses would have to be left between the ends of the plots.

But besides the technical difficulties, it may be impossible to use the Latin Square for lack of room, since the repetitions must equal the number of varieties or treatments to be tested. In such cases it is often possible to use Equalized Random blocks,* which enable the principle of the Latin Square to be used without the very large number of repetitions. For example, the writer was able to suggest an arrangement to a horticultural experimenter who wished to compare ten treatments with five plots of each. He was anxious to use the Latin Square, but realized that if he used two Latin Squares the two sets of five treatments would not be properly comparable.

The proposed arrangement included five randomized blocks, but, whereas the first was completely random, each further successive block had its randomness more and more controlled, just as each successive row in a Latin Square.

It will be seen that each column can equally be considered a "block," and that with one small exception it is as "equalized" as a Latin Square: a fertility slope, therefore, either in the direction of the rows or of the columns, does not introduce errors, and the error of a comparison will be correspondingly reduced. The exception is that owing to there being an odd number of blocks, A, D, E, F, and J occur

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* I have seen no account of work planned in this way, but it is an obvious application of Fisher's methods.—"STUDENT."

YIELD TRIALS (*Continued*)—

in the top row of their block three times and in the lower row twice, and *vice versa* with the others.

G F	H D	E J	C B	A I	Block I.
H B	J G	D I	F A	E C	Block II.
E J	I B	A C	G H	D F	Block III.
C A	F E	B G	I D	J H	Block IV.
D I	A C	F H	J E	B G	Block V.
Block 1.	Block 2.	Block 3.	Block 4.	Block 5.	

FIG. 45.

To sum up, the following methods of testing yields have been described:

On the small scale:

(*a*) Beaven's chessboard.
(*b*) Rod rows.

On the large scale:

(*c*) Beaven's half-drill strip.

Applicable to either large or small scale:

(*d*) Fisher's randomized blocks.
(*e*) Fisher's Latin Square and its modification, Equalized Random blocks.

In the foregoing all reference to two methods—namely, the use of "control" plots, and the estimation of yield from samples taken from the plots instead of by harvesting the whole plots—has been omitted.

The former method was never very satisfactory (R. Summerby, "Accuracy in Field Experiments," *J. Am. Soc. Agron.*, vol. xvii., No. 3), and it was quite usual for "corrections" based on the "control" plots to increase the error of comparisons: it has now been superseded by the methods outlined above.

The latter method, on the other hand, has not yet been fully worked out, though it appears likely that in some cases it will become the

YIELD TRIALS (*Continued*)—

ordinary way of estimating yield (F. L. Engledow, "A Census of an Acre of Corn," *J. Agric. Sci.*, vol. xvi., p. 191, 1926; A. R. Clapham, "The Estimation of Yield in Cereal Crops by Sampling Methods," *J. Agric. Sci.*, vol. xix., p. 214; J. Wishart and A. R. Clapham, "A Study in Sampling Technique: The Effect of Artificial Fertilisers on the Yield of Potatoes," *J. Agric. Sci.*, vol. xix., p. 600). Care should, of course, be taken to discount any sources of error, such as loss of corn from shattered ears, which may take place in one variety on the large scale, but not in samples cut by hand.

Statistical Interpretation of Results—For an adequate exposition of the methods of statistical analysis the reader is referred to treatises on the subject (R. A. Fisher, *loc. cit.*), but an indication of how it comes about that we must invoke the aid of mathematics to make the most of our experiments may not be amiss.

To take a very simple case: Suppose A and B are compared in 1927 and 1928, also C and D, and the following results obtained:

Year.	*Yield per Acre in Cwts.*			
	A.	B.	C.	D.
1927 . ..	20	23	20	29
1928 . ..	19	24	21	20

In each case there is an average difference of 4 cwts. between the pairs, yet most people would probably conclude instinctively that more reliance could be placed in the comparatively concordant differences between A and B than in the discordant results for C and D. We therefore tend to give weight to *concordance.*

Again, suppose a further experiment in 1929 gave $\frac{A}{22}\ \frac{B}{26}$, we should probably feel satisfied that our conclusion that B is better yielding than A is strengthened; we therefore put more reliance on *increased repetition of experiments.* But suppose that instead we had repeated the C D comparison and obtained $\frac{C}{18}\ \frac{D}{22}$, would the three C D comparisons which include the discordant 1928 result be better than the two A B comparisons, concordant though they were?

Clearly we cannot answer questions of this kind by unaided common sense, but fortunately mathematicians have dealt with the evidential value of events of this nature, and we can use the methods and tables of the theory of chance, provided always we make certain that the fundamental condition of applying the theory—namely, that *the events with which we deal are random*—is adequately satisfied.

Randomness—In view of this proviso it is important to have a clear idea of what constitutes randomness, and this is by no means easy.

In our particular case a series of yields would be random if the

YIELD TRIALS (*Continued*)—

value of each of them in relation to those of the others were quite independent of its position in time and place relative to them.

As mentioned above, this does not happen in practice; yields of plots situated close to one another are more alike than those far apart, and in particular there is a general tendency for yields to increase or decrease as we go from one end or side of the experimental area to the other. It is therefore necessary to arrange the positions in such a way as to superpose randomness upon the biassed fertility of the soil. This may be done in two ways: either the positions may be assigned by one of the recognized methods of invoking chance—dice throwing, coin tossing, card drawing, and the like—or a regular pattern may be devised which will equalize the more probable variations in fertility, but which will yet be sufficiently complicated for it to be a matter of chance how the residual variations may affect any particular comparison.

Thus in Fisher's Randomized blocks each treatment is repeated once per block, ensuring that each shall be equally affected by such variation as is common to the block, but the position within the block is determined by chance; similarly, the variation in fertility common to the plots which make up any row or column of a Latin Square is equally shared, but the positions in the row or column are determined by chance.

Beaven's chessboard system, on the other hand, depends on a regular arrangement, but one which is sufficiently complicated for the claim to be made that, by imposing it upon the ordinary variation in the soil, we get in fact a randomness in the residual variation from the mean of each small group of consecutive plots, which enables us to take advantage of mathematical analysis. Nevertheless, we must be careful to avoid arrangements in which the mean position of the different strains is not the same for all, and also such an order as:

A	E	D	C	B
B	A	E	D	C
C	B	A	E	D
D	C	B	A	E
E	D	C	B	A

where a possible crest or trough of fertility parallel to the diagona of A's might improve or depress the yield of one variety, without any warning being given by the calculation of a large error of observation from the observations.

Beaven's half-drill strip is, essentially, in a rather different position. Its pattern is of the simplest, it can only vary between A B B . . . B B A and A B B . . . A A B, of which the former must be chosen in case there may be, as is probable, a " fertility slope " across the

YIELD TRIALS (*Continued*)—

drills. The extreme length and narrowness, however, ensure that the difference between adjacent half-drill strips is otherwise random on ordinary soils, but it is necessary to avoid possible periodic variations in fertility parallel to the drills. Thus, if the field had been laid up in "lands," and the drills were of such a width that the bottom of the land was always occupied by the same strain, a non-random system of error would be included which would vitiate the result. Similarly, a periodic variation in fertility might be left by previous cultivation, and to avoid this, Dr. Hilgendorf of the Canterbury Agricultural College, New Zealand, drills diagonally across previous cultivation.

Analysis of Variance—With suitable precautions, then, all these arrangements give results which can be treated by the methods of the Theory of Chance, and, as it happens, the particular method ("The Analysis of Variance") introduced by Fisher, primarily for this purpose (R. A. Fisher, *loc. cit.*), can be applied to all of them, and I have limited my discussion of the Theory of Chance to such considerations as seem to me to be necessary to an understanding of this method.

If, then, an experiment is repeated several times, we get as a rule as many different results, though by chance some may be identical. If these results are random, we may attach more weight to their mean value the more numerous and the more concordant they are.

The measure of the weight to be given to a Mean is the standard Deviation (S.D. or σ), which is derived as a rule from the results themselves by the following procedure:

Taking the difference between each result and the Mean, it is squared, and the sum of these squared differences is divided by the number of experiments less one. The quotient is called the "Variance" of the results, and the square root of the Variance is the Standard Deviation.

The Variance of the Mean is obtained by dividing the Variance of the results by their number, and, as before, the Standard Deviation of the Mean is the square root of its Variance.

In algebraical notation, if x_1, x_2 . . . x_n be n experimental results, and $\bar{x}$ their mean, then—

The Variance $$= \frac{S_n^1 \ (x - \bar{x})^2}{n - 1}.$$

The Standard Deviation, σ, $$= \sqrt{\frac{S_n^1 \ (x - \bar{x})^2}{n - 1}}.$$

The Variance of the Mean $$= \frac{S_n^1 \ (x - \bar{x})^2}{n(n - 1)}.$$

and the S.D. of the Mean $$= \sqrt{\frac{S_n^1 \ (x - \bar{x}^2)}{n(n - 1)}}.$$

Having obtained the S.D., we can, by referring to tables constructed for this purpose, find the chance that the mean of an infinite number of repetitions under the same conditions would differ by less than any given amount from the mean of the few experiments which we have made. Thus a difference as large as, or larger than, once the S.D. of

YIELD TRIALS (*Continued*)—

the mean of a large number of results occurs 16 times in 100 such series of experiments; as large as, or larger than, twice the S.D. about 2·3 in 100; as large as, or larger than, 3 times the S.D. only about 0·13 time in 100, and thereafter its rarity increases very rapidly.

We can thus judge of the value of our evidence, and as in other matters, the degree of accuracy which we demand will depend on the importance of the action to be taken relative to the cost of repeating the experiments.

For many purposes a probability of twenty to one is considered sufficient to justify drawing a conclusion, and a result which leads to such a probability is often conventionally called "significant." This corresponds to a quantity 1·65 times the S.D., when the S.D. is known accurately.

Now it can be shown that, provided randomness has been observed, variances are additive. If one set of causes, say the innate differences in fertility between the strains which are being tested (Variance V_s), act simultaneously with another set of causes, say random errors of the plots which are being tested (Variance V_e), then if V_t be the total variance of the yields,

$$V_t = V_s + V_e.$$

Similarly, if we can arrange the plots as in randomized blocks, or the sets of Beaven's chessboard, so that part of the variation is common to the blocks or sets (Variance V_b) and part random (V_e as before),

then: $$V_t = V_s + V_b + V_e.$$

Or in the Latin Square:

$$V_t = V_s + V_{\text{rows}} + V_{\text{columns}} + V_e.$$

In any of these cases it is the differences between the strains which make up V_s about which we have to form a judgment, and it is $\sigma_e = \sqrt{V_e}$ with which we have to measure the certainty.

Now V_t is calculable, it is the total variance of the yields, and V_s, V_b, etc., are the variances of the means of the strains, of the means of the blocks, etc., so that we can find V_e by difference.

Degrees of Freedom—But before giving an example of the determination of V_e by this method, it is necessary to introduce the reader to one other technicality.

It will have been noticed that in calculating the variance the sum of the squares was divided not by n the number of results, but by one less than that number. The reason for this is that since we do not know what would be the mean value of an infinite number of results obtained under like conditions, we are driven to use the mean of the n results which we have, and it can be shown that this would necessarily give too low a result were we to divide by n. We are on the average right if we diminish that number by one.

Now for any given mean it is only possible to vary $n-1$ of the results, the last one is fixed by the mean and the other $n-1$; hence, there are said to be $n-1$ *degrees of freedom*. If in addition to the

YIELD TRIALS (*Continued*)—

mean of the whole we also calculate from the mean of a group, say the yield of the plots of a given strain, the number of results which can vary is again diminished by one, there are now but $n - 2$ degrees of freedom, and similarly for each such mean. But it should be noticed that if the general mean and the means of all the strains but one are calculated, the remaining one is now fixed—*i.e.*, the means of the strains, too, have a degree less freedom than the number of the strains.

In this way the original $n - 1$ degrees of freedom may be allotted to the different variances with which we are dealing, each variance accounting for one less than the number of categories from which it is calculated, and the balance is left for the calculation of the Random Variation. Thus, in a Latin Square in which five strains are tested in twenty-five plots there are:

5 strains taking up 4 degrees of freedom.
5 rows ,, 4 ,, ,,
5 columns ,, 4 ,, ,,

So that of the original 24 degrees of freedom only 12 are left for the calculation of the Variance due to Random Error.

We are now in a position to calculate a very simple numerical example.

Suppose we had arranged plots of four strains (A, B, C, and D) in a Latin Square as follows:

A	B	C	D
C	D	A	B
D	C	B	A
B	A	D	C

and that the following yields had been obtained:

5	8	4	2
5	4	2	5
3	6	3	5
5	2	1	4

Can we say that the yield of B under the conditions of the experiment is significantly better than that of D?

For simplicity the above yields have been chosen so that the general mean is a whole number, 4, and in working we may rewrite the yields as differences from that number, thus:

YIELD TRIALS (*Continued*)—

	Sums of Rows.	*Average.*		*Average.*
			Also:	
+1 +4 0 −2	+3	$+\frac{3}{4}$	A = +1 − 2 + 1 − 2 = −2	$-\frac{1}{2}$
+1 0 −2 +1	0	0	B = +4 + 1 − 1 + 1 = +5	$+1\frac{1}{4}$
−1 +2 −1 +1	+1	$+\frac{1}{4}$	C = 0 + 1 + 2 + 0 = +3	$+\frac{3}{4}$
+1 −2 −3 0	−4	−1	D = −2 + 0 − 1 − 3 = −6	$-1\frac{1}{2}$
Sums of Columns +2 +4 −6 0	0			
Average $+\frac{1}{2}+1-\frac{3}{2}$ 0				

The *total variance* then is the sum of the squares divided by the 15 degrees of freedom; or fifteen times $V_t=(1+16+0+4+1+0+4+1+1+4+1+1+1+4+9+0)=48$.

The contribution made to this by the variance of the strains is $\frac{1}{4}$ for each A, $\frac{25}{16}$ for each B, and so forth, or—

$$4\left\{\frac{1}{4}+\frac{25}{16}+\frac{9}{16}+\frac{9}{4}\right\}=18\tfrac{1}{2}.$$

It will be seen that this result can be arrived at more easily by taking $\frac{1}{4}$ of the squares of the sums, *i.e.*:

$$\tfrac{1}{4}(4+25+9+36)=18\tfrac{1}{2}.$$

Similarly, the contribution made by the Variance of the Rows is:

$$\tfrac{1}{4}(9+0+1+16)=6\tfrac{1}{2}.$$

And the contribution made by the Variance of the Columns is:

$$\tfrac{1}{4}(4+16+36+0)=14.$$

These facts are then set out in a table as follows:

Variance due to—	*Degrees of Freedom.*	*Sums of Squares.*	*Variance.*	*Standard Deviation.*
Strains	3	18½	6·17	—
Rows	3	6½	2·17	—
Columns	3	14	4·67	—
Random error	6	9	1·5	1·225
Total	15	48	3·2	—

the degrees of freedom and the sum of the squares due to Random Error being obtained by differences between the total and the sum

YIELD TRIALS (*Continued*)—

of the other three; the variance is obtained by dividing the third column by the second, and the Standard Deviation by taking the square root of the variance.

Now the average difference between B and D is $2\frac{3}{4}$, and the random variance of each mean is $\frac{1\cdot5}{4}$, but since we are dealing with the difference between the two, the variance of this difference is twice this or $0\cdot75$, and the Standard Deviation is $\sqrt{0\cdot75}$, or $0\cdot866$. The difference between B and D is, therefore, $\frac{2\cdot75}{0\cdot866}=3\cdot17$ times the S.D., and is to be looked out opposite $t=\frac{3\cdot1}{3\cdot2}$ in the column headed by 6 degrees of freedom.

With standard deviations calculated from so few degrees of freedom, "Student's" tables must be used: these tables are given in full in *Metron*, vol. iii., 1925; an abstract is given in Fisher's "Statistical Methods for Research Workers," 1st edit., p. 137, and they are also given in a somewhat less convenient form in *Biometrika*, vol. xi., p. 416, and "Tables for Statisticians and Biometricians," 2nd edit., p. 63. If using the last two, the 3·17 must be divided by the square root of one more than the degrees of freedom, and looked out under the column headed by the same number—*i.e.*, we look out $\frac{3\cdot17}{\sqrt{7}}$.

In any case we find the probability of obtaining a smaller difference by chance to be about 0·99—*i.e.*, it is 99 to 1 against getting such a large one—and we may therefore suppose that the difference between B and D would again come out in favour of B, if B and D were grown again under similar conditions.

On the other hand, the difference between C and A is only $\frac{1\cdot25}{0\cdot866}$ times its standard deviation, say 1·45, and on looking this up we find the probability of obtaining a smaller result by chance is only 0·9—*i.e.*, the odds are only 9 to 1 against getting such a large difference, and we cannot conclude that the difference between C and A is due to the strains and not to the positions of the plots in which they are grown.

It should be noticed, however, that the formula which we have used in comparing B and D is that which it is correct to use when there are but two means to compare: it would be right to use it, for example, if we have a number of trials of B and D in different places or seasons, and we wish to examine the whole series of comparisons of B and D.

If, however, there is no particular reason why we should compare these two rather than any other pair, it is clear that the chance of obtaining a large difference between some pair or other is greater the larger the number of possible pairs. To meet this Fisher suggests that the mean of each strain should be compared with the general mean, and that the strains should be divided in this way into—

YIELD TRIALS (*Continued*)—

(*a*) Those significantly greater than the mean;
(*b*) Those not differing significantly from the mean; and
(*c*) Those significantly less than the mean.

The appropriate Standard Deviation to use, if σ be the Standard Deviation of the Random Error of a single plot, and there are n repetitions and m strains, is:

$$\frac{\sigma\sqrt{m-1}}{\sqrt{n\,m}}$$

In this case $n=m=4$, and the S.D. is therefore $1{\cdot}225\times\frac{\sqrt{3}}{4}=0{\cdot}53$. Referring to the table, we find that the 20 : 1 limit corresponds to twice the S.D. ($t=2{\cdot}0$) for 6 degrees of freedom, and accordingly we may divide the four strains as follows:

B, significantly better than the mean;
A and C, not different significantly from the mean; and
D, significantly worse than the mean.

The above example, though " made up," illustrates what commonly happens in practice—namely, that the Variance of the Rows and of the Columns which we have neutralized in the arrangement of the Latin Square is in each case greater than the Random Error, and we have therefore increased the precision of our experiment by this arrangement.

It is not usual, however, to have an exact figure as the mean, and the following example of a half-drill strip experiment which was actually carried out at Ballinacurra, Co. Cork, in 1929, gives the procedure when measuring not from the mean, but, to avoid working with fractions, from some arbitrarily chosen origin. This trial compared a selection from Dr. Hunter's Spratt-Archer barley with his selected Archer in twenty-two half-drill strips each. It will be noticed that when Spratt-Archer was on the *north*, there was practically no difference, but that it was markedly better when on the *south*; thus there was a fertility slope across the strips, and the two sets should be averaged separately at the loss of a degree of freedom.

Naturally with only two varieties to compare we do not concern ourselves with anything but the differences between corresponding strips, and to avoid fractions, these differences are measured in ¼-lb. units. The mean is here fractional, and to save arithmetic, an arbitrary point is chosen as origin. Now any arbitrary origin may be chosen, but since the largest difference is +40 and the smallest − 24, the obvious origin is zero. [A useful exercise for the beginner would be to take another origin (say +10), measure each difference from this, and work out the example again; the same result should be obtained, and to facilitate an exercise of this kind the figures which should be identical in any such comparison are given in italics.

Thus, if +10 were chosen the differences would run:

+4 +25 − 34 − 6 − 16, and so on.]

YIELD TRIALS *(Continued)*—

TABLE OF YIELDS.

	Yields.		*Difference, SA.-A.*	
	Spratt-Archer, 37, *No.* 3.	*Archer.*	*Spratt-Archer on North.*	*Spratt-Archer on South.*
	Lbs.	Lbs.	¼ lbs.	¼ lbs.
	36½	33	+14	
	41½	32¾		+35
	34	40	−24	
	40	39		+ 4
	37	38½	− 6	
	37½	36¼		+ 5
	38½	35	+14	
	42¼	38½		+15
	41	42½	−6	
	43	40		+12
	42¼	42	+ 1	
	42	38½		+14
	41	39¼	+ 7	
	45	38½		+26
	44¼	42	+ 9	
	42¼	40½		+ 7
	40	39½	+ 2	
	41	39½		+ 6
	41	39	+ 8	
	39½	41¼		− 7
	36	39½	−14	
	43	33		+40
Sum ..	888½	848	+ 5	+157
			+162	
Average ..	40·4	38·5	+7·364	

I owe these figures to the courtesy of the Irish Free State Department of Agriculture.—"STUDENT."

We have first the sum of the squares of all differences:

196 + 1,225 + 576 + 16 + 36 + 25 + 196 + 225 + 36 + 144 + 1 + 196 + 49 + 676 + 81 + 49 + 4 + 36 + 64 + 49 + 196 + 1,600 .. .. = 5,676

To correct for the arbitrary origin we subtract 22 times the square of the mean distance from the origin, *i.e.*, $22 \times 7{\cdot}364^2$ .. .. = 1,193

4,483

The sum of the squares due to the north/south fertility slope is:

$\frac{1}{11}(5^2+157^2)$ .. .. = 2,243

Subtracting the same correction for the arbitrary mean .. .. = 1,193

We get *1,050*

YIELD TRIALS (*Continued*)—

We now arrange as before:

Variance due to—	*Degrees of Freedom.*	*Sums of Squares.*	*Variance.*	*Standard Deviation.*
North/South Fertility Slope	1	1,050	1,050	
Random Error	20	3,433	171·65	13·1
Total	21	4,483	213·5	

It will be observed that all the figures in this table are the same no matter what arbitrary origin is chosen, and this method is the same no matter how many different sources of variance are accounted for; the same correction (the square of the mean multiplied by the *total* number) is subtracted from the sum of squares due to each source and from the total.

The mean difference is then 7·364 in favour of Spratt-Archer 37, No. 3, and the variance of the comparison is $\frac{171 \cdot 65}{22}$, giving a Standard Deviation of 2·79 (about 1·7 per cent.), and we have—

$$t = \frac{7 \cdot 364}{2 \cdot 79} = 2 \cdot 64.$$

Looking this out in the table under 20 degrees of freedom, we find $P = 0 \cdot 9921$; *i.e.*, we should get a result in favour of Spratt-Archer 37, No. 3, as large as this by chance if there were really no difference only 79 times in 10,000 trials, and we may conclude that under the conditions of the trial Spratt-Archer is definitely the higher yielding barley.

The following table gives the variances which are removed in finding the Random Error in the various methods described when calculating the degree of significance of the results by the analysis of variance.

Chessboard (Balanced Panels as recommended).	*Half-drill Strips.*	*Randomized Blocks.*	*Latin Square.*	*Equalized Randomized Blocks.*
Variance of Strains	Variance of Strains	Variance of Strains	Variance of Strains	Variance of Strains.
Variance of Sets		Variance of Blocks	Variance of Rows	Variance of Blocks "across."
Variance of fertility slope in balanced direction	Fertility slope across strips		Variance of Columns	Variance of Blocks "down."

YIELD TRIALS (*Continued*)—

General Observations—While it is obvious that there is much to be gained by planning yield trials in such a way as both to reduce the experimental error and to obtain an accurate estimate of it, *it is important to remember that conclusions can only be drawn applicable to the particular conditions under which the trials were carried out.*

For this reason, trials should be repeated season after season, and in so many different places as to cover the probable variations in soil and climate in the districts in which practical application is to be made.

When this has been done, the accuracy which our technique has enabled us to obtain will enable us to analyze the results, so as to find out whether some of our strains/treatments suit certain soils/seasons/climates better than others.

Moreover, it is not enough to show that one strain/treatment is superior to another in yield; to achieve lasting success we must subject our product to tests for quality.

Thus, the Irish barley trials culminated in malting and brewing tests, as also those now being conducted by the National Institute of Agricultural Botany; Biffen's wheats were chosen for their baking strength, as well as yield, and so on. On the other hand, accounts of yield trials of potatoes rarely conclude with a table of moisture percentages and an estimate of relative palatability (F. Johnson and O'C. Boyle, "The Industrial and Nutritive Value of the Potato in Ireland," *J. Dept. Agric. for Ireland,* vol. xviii., No. 4). This may help to account for the modern potato.

GENERAL REFERENCES.—G. Udny Yule, "Introduction to the Theory of Statistics," Griffin and Co., London; F. L. Engledow and G. Udny Yule, "The Principles and Practice of Yield Trials," *The Empire Cotton Growing Review,* vol. iii., Nos. 2 and 3, Empire Cotton Growing Corporation, Millbank, London; Fisher and Wishart, *Imp. Bur. Soil Science, Tech. Comm.* No. 10, "The Arrangement of Field Experiments and the Statistical Reduction of the Results."

An excellent bibliography of papers, etc., is contained in W. Horton Beckett's "Methods of Field Experimentation," 1928 *Year Book of the Dept. of Agric.,* Gold Coast.

"STUDENT."

ZERO—See Heat, Temperature, and Thermometers.

ZYGOTE—This term is used in biology for the product of the union of two sexually produced cells, the male and female gametes. The ordinary individual among the higher animals or plants, or the embryo which gives rise to it, is therefore a zygote; the sexual cells, and certain stages in the life histories of many lower plants and animals, are not. (See also Mendelism, Cytology.)

END OF VOL. II.

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